

(19)



(11)

EP 4 492 920 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.01.2025 Bulletin 2025/03

(51) International Patent Classification (IPC):
H05B 39/04 (2006.01) H05B 45/10 (2020.01)

(21) Application number: **24187403.1**

(52) Cooperative Patent Classification (CPC):
H05B 39/08; H05B 39/044; H05B 45/10

(22) Date of filing: **09.07.2024**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(72) Inventors:
• **XIONG, Kun**
Shenzhen, 518000 (CN)
• **YANG, Qiming**
Shenzhen, 518000 (CN)
• **LI, Huayu**
Shenzhen, 518000 (CN)

(30) Priority: **10.07.2023 CN 202310840272**

(74) Representative: **Manitz Finsterwald**
Patent- und Rechtsanwaltspartnerschaft mbB
Martin-Greif-Strasse 1
80336 München (DE)

(71) Applicant: **SCHNEIDER ELECTRIC INDUSTRIES SAS**
92500 Rueil-Malmaison (FR)

(54) CONTROL CIRCUIT AND METHOD FOR DIMMING APPARATUS AND DIMMING APPARATUS

(57) Embodiments of the disclosure provide a control circuit and method for a dimming apparatus and a dimming apparatus. The control circuit includes: a dimming signal transmission circuit configured to be coupled to gates of a first field effect transistor and a second field effect transistor of the dimming apparatus; a first turn-off signal part coupled to the gate of the first field effect

transistor and adapted to output a first turn-off signal to turn off the first field effect transistor at a predetermined time before a first current zero-crossing point; and a second turn-off signal part coupled to the gate of the second field effect transistor and adapted to turn off the second field effect transistor at the predetermined time before a second current zero-crossing point.

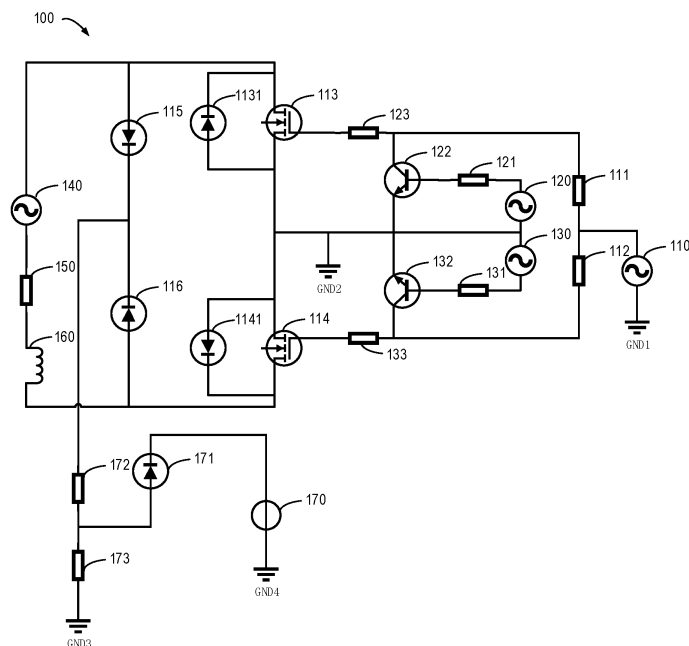


FIG. 1

Description

CROSS REFERENCE

[0001] This application claims the priority to Chinese Patent Application No. 202310840272.1 filed on July 10, 2023, and entitled "Control Circuit and Method for Dimming Apparatus and Dimming Apparatus", which is hereby incorporated by reference in its entirety.

FIELD

[0002] Embodiments of the present disclosure generally relate to the field of dimmer, and in particular to a control circuit and method for a dimming apparatus and a dimming apparatus.

BACKGROUND

[0003] A dimmer is a device or system for controlling light brightness. It may enable adjustment of the brightness of the lighting apparatus by varying the voltage, current, or power supplied to the light fixture by the power supply. Dimers also play an important role in energy conservation and environmental protection. By effectively reducing the lamp power output, dimmers can significantly reduce power consumption and extend lamp life.

[0004] The configuration of a dimmer needs to consider the type of load and maintain stable output. The load typically includes a resistive load and a non-linear load. The non-linear load includes an inductive load and a capacitive load. Thus, accommodating various types of loads is critical to dimmers. For example, a leading-edge dimmer is suitable when connecting an inductive load. Before returning the switch to the off state, it is typically necessary to drop the current half-cycle load current to a level close to zero to avoid excessive levels of induced voltage spikes, which may damage the electrical components of the device.

SUMMARY

[0005] The purpose of embodiments of the present disclosure is to provide a control circuit and method for a dimming apparatus and a dimming apparatus to at least partially solve the above problems and other potential problems.

[0006] In first aspect of the present disclosure, a control circuit for a dimming apparatus is provided. The control circuit includes: a dimming signal transmission circuit configured to be coupled to gates of a first field effect transistor and a second field effect transistor of the dimming apparatus to transmit a dimming control signal from a control unit to control on-off states of the first field effect transistor and the second field effect transistor; a first turn-off signal part coupled to the gate of the first field effect transistor and adapted to, in response to control of

the control unit, output a first turn-off signal during a negative half-cycle of a waveform output by a main AC power supply of a load circuit to turn off the first field effect transistor at a predetermined time before a first current zero-crossing point, to cause current to flow from a body diode of the first field effect transistor before the first current zero-crossing point; and a second turn-off signal part coupled to the gate of the second field effect transistor and adapted to, in response to control of the control unit, turn off the second field effect transistor at the predetermined time before a second current zero-crossing point during a positive half-cycle of a waveform output by a main AC power supply of the load circuit, to cause current to flow from a body diode of the second field effect transistor before the second current zero-crossing point.

[0007] In embodiments of the present disclosure, the first turn-off signal and the second turn-off signal are output by the first turn-off signal part and the second turn-off signal part at a predetermined time before the zero-crossing points of the first current and the second current, respectively, so as to turn-off the first field-effect transistor and the second field-effect transistor, thereby avoiding generation of voltage spikes generated when the dimming apparatus and the inductive load are connected.

[0008] In some embodiments, the dimming control signal is changed to a low-level signal at the first current zero-crossing point and the second current zero-crossing point of the main AC power supply to turn off the first field effect transistor and the second field effect transistor.

[0009] In some embodiments, the first turn-off signal part includes: a first triode, a base of the first triode is coupled to a first turn-off output port of the control unit to receive a control signal from the control unit, a collector of the first triode is coupled to the gate of the first field effect transistor, and an emitter of the first triode is grounded.

[0010] In some embodiments, the second turn-off signal part includes: a second triode, a base of the second triode is coupled to a second turn-off output port of the control unit to receive a control signal from the control unit, a collector of the second triode is coupled to the gate of the second field effect transistor, and an emitter of the second triode is grounded.

[0011] In some embodiments, the control circuit further includes a zero-crossing detection circuit coupled to the load circuit and adapted to detect the first current zero-crossing point and the second current zero-crossing point, and coupled to the control unit to cause the control unit to output at least the dimming control signal based on a detection signal of the zero-crossing detection circuit.

[0012] In a second aspect of the present disclosure, a method for controlling a dimming apparatus is provided. the method includes: during a negative half-cycle of a waveform output by a main AC power supply of a load circuit controlled by the dimming apparatus, outputting a first turn-off signal to turn off a first field effect transistor of the dimming apparatus at a predetermined time before a first current zero-crossing point, to cause current to flow

from a body diode of the first field effect transistor before the first current zero-crossing point; during a positive half-cycle of a waveform output by a main AC power supply of the load circuit, outputting a second turn-off signal to turn off a second field effect transistor of the dimming apparatus at a predetermined time before a second current zero-crossing point, to cause current to flow from a body diode of the second field effect transistor before the second current zero-crossing point; and outputting a dimming control signal from a dimming signal output port to control on-off states of the first field effect transistor and the second field effect transistor.

[0013] In some embodiments, outputting a dimming control signal from a dimming signal output port comprises: changing the dimming control signal to a low-level signal at a current zero-crossing point of the main AC power supply to turn off the first field effect transistor and the second field effect transistor.

[0014] In some embodiments, outputting the first turn-off signal comprises: outputting a first turn-off signal at a high level at the predetermined time before the first current zero-crossing point, to turn off the first field effect transistor by changing an electrical signal acting on a gate of the first field effect transistor to a low-level signal through a first triode.

[0015] In some embodiments, outputting the second turn-off signal comprises: outputting a second turn-off signal at a high level at the predetermined time before the second current zero-crossing point, to turn off the second field effect transistor by changing an electrical signal acting on a gate of the second field effect transistor to a low-level signal through a second triode.

[0016] In some embodiments, the method further includes: obtaining a current zero-crossing point from a zero-crossing detection circuit; and outputting at least the dimming control signal based on a detection signal of the zero-crossing detection circuit relating to the current zero-crossing point.

[0017] In a third aspect of the present disclosure, a dimming apparatus is provided. the dimming apparatus includes: a first field effect transistor and a second field effect transistor connected in series in a load circuit controlled by the dimming apparatus and respectively comprising a gate, a source and a drain, the sources of the first field effect transistor and the second field effect transistor being connected; and a control circuit according to the first aspect, coupled to the first field effect transistor and the second field effect transistor.

[0018] It should be understood that the content described in this content section is not intended to limit the key features or important features of the embodiments of the present disclosure, nor is it intended to limit the scope of the present disclosure. Other features of the present disclosure will become readily understood from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The above and other features, advantages, and aspects of various embodiments of the present disclosure will become more apparent from the following detailed description taken in conjunction with the accompanying drawings. In the drawings, the same or similar reference numbers refer to the same or similar elements, wherein:

FIG. 1 illustrates a schematic diagram of a control circuit according to embodiments of the present disclosure;

FIG. 2 illustrates a schematic diagram of a simulation of the control circuit shown in FIG. 1;

FIG. 3 illustrates a flowchart diagram of a method of control circuit according to the present disclosure; and

FIG. 4 illustrates a schematic block diagram of a dimming apparatus 400 suitable for implementing embodiments of the present disclosure.

DETAILED DESCRIPTION

[0020] Preferred embodiments of the present disclosure will be described in more detail below with reference to the accompanying drawings. While the preferred embodiments of the present disclosure are shown in the drawings, it should be understood that the present disclosure may be implemented in various forms and should not be limited by embodiments set forth herein. Rather, these embodiments are provided to make this disclosure more thorough and complete, and to fully convey the scope of the present disclosure to those skilled in the art.

[0021] As used herein, the term "comprising" and deformation thereof represent openness, i.e., "including but not limited to". Unless specifically stated, the term "or" means "and / or". The term "based on" means "based at least in part on". The terms "an example embodiment" and "an embodiment" mean "at least one example embodiment". The term "another embodiment" means "at least one further embodiment". The terms "first," "second," and the like may refer to different or identical object.

[0022] As briefly mentioned above, with the development of digital technology, dimmers also play an important role in energy conservation and environmental protection. For example, a Phase-controlled dimmer, also known as a dimmer switch or electronic dimmer, is an apparatus for controlling lamp brightness. The dimmer realizes the dimming function by changing the voltage magnitude supplied to the bulb by the AC power supply. The Phase-controlled dimmer uses Zero Crossing Detection to accurately detect and record the zero position of a sine wave. When the user sends a dimming signal through a knob, a switch, or a remote controller, the

Phase-controlled dimmer receives the signal and performs decoding processing.

[0023] According to the user-set brightness level, the Phase-controlled dimmer will turn on the circuit to supply power to the bulb when it is near the next AC cycle zero-crossing. This may reduce the risk of shock and damage caused by the sudden application of high voltage and maintain precise control of the bulb output energy. By continuously delaying the opening time, the gradient effect at different brightness levels can be achieved. Phase-controlled dimmer provides a wider range, smoother, and precise brightness selectable range than conventional linear cutting methods, such as variable resistance. In addition, it also has the advantages of low power consumption, easy installation and operation, and the like. Phase-controlled dimmer is widely used in home, commercial, and industrial lighting system, provides customized lighting experiences for users, and achieves goals of energy conservation and environmental protection.

[0024] However, when a conventional Phase-controlled dimmer is used with an inductive load, a spike voltage problem may occur. This is because an inductive load (such as an inductive coil) generates a self-inductive reaction when the inductive load is powered off, resulting in a current unable to quickly fall to zero. Thus, the current that has not completely disappeared will continue through the load before the next half wave of the AC cycle begins. In this case, when the Phase-controlled dimmer is turned on again to provide power to the load, there is a peak voltage (also referred to as spike voltage) that exceeds the expected and design parameters within the normal operating range. This may result in damage, overheating, or even failure of the light fixture or other device.

[0025] To solve this problem, there are two methods in the conventional solution. The first method is to use a series current sense resistor and a precision operational amplifier device to determine when the load current drops to a sufficiently low level so that the switch can be turned off at the minimum voltage spike level. However, since the current sense resistor increases the total resistance of the dimming apparatus, this method has the disadvantage of easily causing the dimming apparatus to consume more power. The second method is to use a non-zero current MOSFET turn-off method. For example, for a load that is only marginal (e.g., a typical core based 25 LV lighting), the MOSFET may be turned off at a point in time corresponding to the power supply voltage crossing zero. However, this method is only applicable to loads with only less inductive loads and cannot be used for larger inductive loads or inductive loads.

[0026] In order to solve or at least partially solve the above problems or other potential problems existing in the Phase-controlled dimmer of the conventional solution, embodiments of the present disclosure provide a control circuit and method for a dimming apparatus and a dimming apparatus. In the control circuit, during the

negative half cycle of the waveform output by the main AC power supply of the load circuit, the first turn-off signal is output by the first turn off signal unit at a predetermined time before the first current zero-crossing point, thereby turning off the first field effect transistor. During a positive half cycle of the waveform output by the main AC power supply of the load circuit, a second turn-off signal is output by the second off signal at a predetermined time before the second current zero crossing point, so as to turn off the second field effect transistor, so that the current flows through the body diode (also referred to as an "anti-parallel diode") of the first field effect transistor or the second field effect transistor before the first current zero-crossing point or the second current zero-crossing point. Therefore, the self-inductance energy generated by the inductive load is suppressed and absorbed, for example, the voltage spikes generated when the dimming apparatus is connected with the inductive load, and the lamp or other equipment is protected from being damaged by the peak voltage, and the correct connection and grounding are ensured to ensure the stability and securability of the system.

[0027] FIG. 1 illustrates a schematic diagram of a control circuit according to embodiments of the present disclosure, and FIG. 2 illustrates a schematic diagram of a simulation of the control circuit shown in FIG. 1. The principles of the present disclosure will be described in detail below with reference to FIGS. 1 to 2. First, refer to FIG. 1, which illustrates a schematic structural diagram of a control circuit 100 for a dimming apparatus according to embodiments of the present disclosure. As shown in FIG. 1, the control circuit 100 for the dimming apparatus described herein generally includes a dimming signal transmission circuit, a first turn-off signal part and a second turn-off signal part. The dimming signal transmission circuit, the first turn-off signal part and the second turn-off signal part are both coupled to the control terminals (i.e., gates) of the two field-effect transistors of the dimming apparatus to control the turn-on and turn-off of the two field-effect transistors, respectively. The first switch-off signal part and the second switch-off signal part respectively turn off the corresponding field effect transistor at a predetermined time (for example, 2ms) before the current zero-crossing point, which can ensure that the current half-cycle load current drops to zero at the zero-crossing point, thereby effectively avoiding damage to the lamp or other equipment by the peak voltage of the dimming apparatus. In addition, the dimming apparatus in the present disclosure also has the advantages of low power consumption, easy installation and operation, and the like.

[0028] The specific structure of the control circuit will be described below with reference to FIG. 1. As shown in FIG. 1, the dimming signal transmission circuit is configured to be coupled to the gates of the first field effect transistor 113 and the second field effect transistor 114 of the dimming apparatus to transmit the dimming control signal from the control unit. The dimming control signal,

for example, corresponds to the "3Gate on" signal in FIG. 2, and may be used to control the on-off of the first field effect transistor 113 and the second field effect transistor 114. In some embodiments, the first field effect transistor 113 and the second field effect transistor 114 in the present disclosure may include a metal-oxide-semiconductor field-effect transistor (also referred to as a MOS-FET or a MOS transistor), and may adopt a PMOS transistor, which is not limited in the present disclosure. In the present disclosure, the dimming signal transmission circuit may include a transmission line from the dimming signal output port 110 of the control unit to the gate of the first field effect transistor 113 and the second field effect transistor 114, and a plurality of resistors (e.g., the resistor 111, the resistor 112, the resistor 113, the resistor 133 shown in FIG. 1) coupled to the transmission line. Specifically, the resistor 111 and the resistor 123 are connected in series between the control unit dimming signal output port 110 and the gate coupled to the first field effect transistor 113 through a transmission line, and the resistor 112 and the resistor 133 are connected in series between the control unit dimming signal output port 110 and the gate of the second field effect transistor 114 through a transmission line for controlling transmission of the dimming signal.

[0029] In some embodiments, the source of the first field-effect transistor 113 is coupled to the source of the second field-effect transistor 114. A load circuit is provided between the drain of the first field effect transistor 113 and the drain of the second field effect transistor 114. The load circuit is a circuit that includes a main AC power supply 140, a resistive load 150, and an inductive load 160 (or a resistive and inductive part referred to as a load). The on/off of the load circuit is realized by controlling the on-off of the first field effect transistor 113 and the second field effect transistor 114.

[0030] In some embodiments, the first turn-off signal part is coupled to the gate of the first field-effect transistor 113, and is capable of outputting the first turn-off signal under the control of the control unit at a predetermined time (for example, 2ms or any other suitable time) before the current zero-crossing point (hereinafter referred to as the first current zero-crossing point) of the negative half-cycle during a negative half-cycle of a waveform output by a main AC power supply of a load circuit, thereby turning off the first field-effect transistor 113, so that the current flows from the body diode 1131 of the first field-effect transistor 113 before the first current zero-crossing point.

[0031] As shown in FIG. 2, the dimming control signal (3Gate on signal) changes a low-level signal at the first current zero-crossing point and the second current zero-crossing point of the main AC power supply to turn off the first field-effect transistor 113 and the second field-effect transistor 114.

[0032] In some embodiments, the first turn-off signal part includes a first triode 122. The base of the first triode 122 is coupled to the first turn-off output port 120 of the

control unit to receive the first turn-off signal (e.g., the 4off1 signal shown in FIG. 2) from the control unit, the collector of the first triode 122 is coupled to the gate of the first field-effect transistor 113, and the emitter of the first triode 122 is grounded. In this way, when the first turn-off output port 120 of the control unit outputs a first turn-off signal (for example, the 4off1 signal shown in FIG. 2) at a high level at a predetermined time before the first current zero-crossing point, the collector and the emitter of the first triode 122 will be turned on, thereby pulling down the level of the gate of the first field-effect transistor 113 to achieve the effect of turning off the first field-effect transistor 113. At this time, current flows from the body diode 1131 of the first field effect transistor 113 until the current crosses zero.

[0033] Since the first field effect transistor 113 is turned off before reaching the first current zero-crossing point, the current flows from the body diode 1131 of the first field effect transistor 113 before the first current zero-crossing point, and since the body diode 1131 is an anti-parallel diode of the first field effect transistor, the first current is prevented from flowing in a reverse direction, so that when power is again provided to the load, the peak voltage generated by the first current can be suppressed.

[0034] Similarly, in some embodiments, the second turn-off signal part is coupled to the gate electrode of the second field-effect transistor 114, and is capable of turning off the second field effect transistor 114 at a predetermined time before the current zero-crossing point (hereinafter referred to as the second current zero-crossing point) of the positive half-cycle during the positive half-cycle of a waveform output by a main AC power supply of a load circuit, so that the current flows from the body diode 1141 of the second field-effect transistor 114 before the second current zero-crossing point.

[0035] In some embodiments, the second turn-off signal part includes a second triode 132. The base of the second triode 132 is coupled to the second turn-off output port 130 of the control unit to receive the second turn-off signal (e.g., the 5off2 signal shown in FIG. 2) from the control unit, the collector of the second triode 132 is coupled to the gate of the second field-effect transistor 114, and the emitter of the second triode 132 is grounded. In some embodiments, the first turn-off output port 120 and the second turn-off output port 130 of the control unit may be the same port on the control unit or different ports.

[0036] Similar to the case of the first triode 122, when the second turn-off output port 130 of the control unit outputs a second turn-off signal (for example, the 5off2 signal shown in FIG. 2) at a high level at a predetermined time before the second current zero-crossing point, the collector and the emitter of the second triode 132 will be turned on, thereby pulling down the level of the gate of the second field-effect transistor 114 to achieve the effect of turning off the second field-effect transistor 114. At this time, current flows from the body diode 1141 of the second FET 114 until the current crosses zero.

[0037] Similar to the first turn-off signal part, since the

second field effect transistor 114 is turned off before the current reaches the zero point, the current flows from the body diode 1141 of the second field effect transistor 114 before the second current zero crossing, and since the body diode 1141 is an anti-parallel diode of the second field effect transistor 114 to prevent the second current from flowing in a reverse direction, so that when power is again provided to the load, the high peak voltage generated by the second current can be suppressed.

[0038] In some embodiments, the first triode 122 and the second triode 132 in the present disclosure may be NPN type transistors. A resistor 121 may be provided between the base of the first triode 122 and the first turn-off signal output port 120 of the control unit, and a resistor 131 may be provided between the base of the second triode 132 and the second turn-off signal output port 130 of the control unit. As mentioned above, the predetermined time before the first current zero-crossing point and the second current zero-crossing point in the present disclosure may be 2 milliseconds (ms), or certainly may be set to 3 milliseconds, 5 milliseconds, or any other suitable time, which is not limited in the present disclosure.

[0039] Therefore, when the waveform output by the first triode 122 and the second triode 132 in the main AC power supply of the load circuit is in the positive half cycle and the negative half cycle, respectively, the first field effect transistor 113 and the second field effect transistor 114 are controlled to be turned off, and when the dimming apparatus is connected to the inductive load, the generation of the peak voltage at the current zero-crossing point is avoided.

[0040] In some embodiments, the control circuit further includes a zero-crossing detection circuit. The zero-crossing detection circuit is coupled to the load circuit, and is adapted to detect the first current zero-crossing point and the second current zero-crossing point, and the zero-crossing detection circuit is coupled to the signal input 170 of the control unit to cause the control unit to output at least the dimming control signal based on a detection signal of the zero-crossing detection circuit. In addition, in some embodiments, the control unit may further output the first turn-off signal or the second turn-off signal mentioned above at a predetermined time before the current zero-crossing point according to the first current zero-crossing point and the second current zero-crossing point detected by the zero-crossing detection circuit to effectively suppress the generation of the high peak voltage.

[0041] In some embodiments, the zero-crossing detection circuit in embodiments of the present disclosure may include a first diode 115, a second diode 116, a resistor 172, a resistor 173, and a third diode 171. The negative electrode of the first diode 115 is connected to the negative electrode of the second diode 116, and the two are connected in parallel with the load circuit. The resistor 172 and the resistor 173 are connected in series. Specifically, one end of the resistor 172 is connected

between the first diode 115 and the negative electrode of the second diode 116, the other end of the resistor 172 is connected to one end of the resistor 173, and the other end of the resistor 173 is grounded. A positive electrode of the third diode 171 is connected between the resistor 172 and the resistor 173, and a negative electrode of the third diode 171 is connected to the signal input portion 170 of the control unit.

[0042] As shown in FIG. 2, 1Vin represents a voltage signal of a main AC power supply, which is in a sinusoidal waveform distribution, 2Current is a current diagram of a load circuit, 3Gate on is a waveform diagram of a dimming control signal, 4off1 is a waveform diagram of a first turn-off signal, 5off2 is a waveform diagram of a second turn-off signal, Diode current is a current waveform of a body diode, V_dimmer is a load voltage waveform, and ZCD is an output signal waveform chart of a zero-crossing detection circuit. As can be seen from FIG. 2, when the zero point is close to the next AC cycle (i.e., the first current zero-crossing point or the second current zero-crossing point mentioned above), the peak voltage is not present at the position close to the current zero-crossing point in the load voltage waveform diagram after the control circuit control operation as described above. Therefore, the control circuit of the present disclosure effectively eliminates the problem of voltage spikes generated when the dimming apparatus and the inductive load are connected.

[0043] FIG. 3 illustrates a flowchart diagram of a method of control circuit according to the present disclosure. In some embodiments, the method 300 may be implemented by a processor of the control unit mentioned above or another suitable device. For ease of understanding, the specific examples, numbers, or values mentioned in the following description are merely exemplary, and are not intended to limit the protection scope of the present disclosure.

[0044] Referring to FIG. 3, at block 310, during a negative half-cycle of a waveform output by a main AC power supply of a load circuit controlled by the dimming apparatus, the control unit outputs a first turn-off signal to turn off a first field effect transistor of the dimming apparatus at a predetermined time before a first current zero-crossing point, to cause current to flow from a body diode of the first field effect transistor before the first current zero-crossing point. At block 320, during a positive half-cycle of a waveform output by a main AC power supply of the load circuit, the control unit outputs a second turn-off signal to turn off a second field effect transistor of the dimming apparatus at a predetermined time before a second current zero-crossing point, to cause current to flow from a body diode of the second field effect transistor before the second current zero-crossing point. At block 330, the control unit outputs a dimming control signal from a dimming signal output port 110 to control on-off states of the first field effect transistor and the second field effect transistor.

[0045] In some embodiments, the control unit changes

the dimming control signal to a low-level signal at a current zero-crossing point of the main AC power supply to turn off the first field effect transistor and the second field effect transistor.

[0046] In some embodiments, the control unit outputs a first turn-off signal at a high level at the predetermined time before the first current zero-crossing point, to turn off the first field effect transistor 113 by changing an electrical signal acting on a gate of the first field effect transistor 113 to a low-level signal through a first triode.

[0047] In some embodiments, the control unit outputs a second turn-off signal at a high level at the predetermined time before the second current zero-crossing point, to turn off the second field effect transistor by changing an electrical signal acting on a gate of the second field effect transistor to a low-level signal through a second triode.

[0048] In some embodiments, the control unit obtains a current zero-crossing point from a zero-crossing detection circuit; and the control unit outputs at least the dimming control signal based on a detection signal of the zero-crossing detection circuit relating to the current zero-crossing point.

[0049] FIG. 4 illustrates a schematic block diagram of a dimming apparatus 400 suitable for implementing embodiments of the present disclosure. As shown in FIG. 4, the dimming apparatus 400 includes a first field effect transistor 113, a second field effect transistor 114, and a control circuit 100. The first field effect transistor 113 and the second field effect transistor 114 are connected in series in a load circuit controlled by a dimming apparatus and include a gate, a source, and a drain, respectively. The sources of the first field effect transistor 113 and the second field effect transistor 114 are connected. The control circuit 100 is coupled to the first field-effect transistor 113 and the second field-effect transistor 114 in the manner described above to thereby effectively avoid the peak voltage generated when the dimming apparatus 400 is connected to the inductive load, thereby effectively ensuring the safe use of the load and the device.

[0050] Various embodiments of the present disclosure have been described above, which are exemplary, not exhaustive, and are not limited to embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the illustrated embodiments. The selection of the terms used herein is intended to best explain the principles of embodiments, practical applications, or technical improvements in the marketplace, or to enable others of ordinary skill in the art to understand embodiments disclosed herein.

Claims

1. A control circuit for a dimming apparatus comprising:
a dimming signal transmission circuit configured to be coupled to gates of a first field effect

transistor (113) and a second field effect transistor (114) of the dimming apparatus to transmit a dimming control signal from a control unit to control on-off states of the first field effect transistor (113) and the second field effect transistor (114);

a first turn-off signal part coupled to the gate of the first field effect transistor (113) and adapted to, in response to control of the control unit, output a first turn-off signal during a negative half-cycle of a waveform output by a main AC power supply of a load circuit to turn off the first field effect transistor (113) at a predetermined time before a first current zero-crossing point, to cause current to flow from a body diode (1131) of the first field effect transistor (113) before the first current zero-crossing point; and

a second turn-off signal part coupled to the gate of the second field effect transistor (114) and adapted to, in response to control of the control unit, turn off the second field effect transistor (114) at the predetermined time before a second current zero-crossing point during a positive half-cycle of a waveform output by a main AC power supply of the load circuit, to cause current to flow from a body diode (1141) of the second field effect transistor (114) before the second current zero-crossing point.

2. The control circuit of claim 1, wherein the dimming control signal is changed to a low-level signal at the first current zero-crossing point and the second current zero-crossing point of the main AC power supply to turn off the first field effect transistor (113) and the second field effect transistor (114).
3. The control circuit of anyone of the previous claims, wherein the first turn-off signal part comprises: a first triode (122), a base of the first triode (122) is coupled to a first turn-off output port (120) of the control unit to receive a control signal from the control unit, a collector of the first triode (122) is coupled to the gate of the first field effect transistor (113), and an emitter of the first triode (122) is grounded.
4. The control circuit of anyone of the previous claims, wherein the second turn-off signal part comprises: a second triode (132), a base of the second triode (132) is coupled to a second turn-off output port (130) of the control unit to receive a control signal from the control unit, a collector of the second triode (132) is coupled to the gate of the second field effect transistor (114), and an emitter of the second triode (132) is grounded.
5. The control circuit any of claims 1-4, further comprising: a zero-crossing detection circuit coupled to the load

circuit and adapted to detect the first current zero-crossing point and the second current zero-crossing point, and coupled to the control unit to cause the control unit to output at least the dimming control signal based on a detection signal of the zero-crossing detection circuit.

6. A method for controlling a dimming apparatus comprising:

during a negative half-cycle of a waveform output by a main AC power supply of a load circuit controlled by the dimming apparatus, outputting (310) a first turn-off signal to turn off a first field effect transistor (113) of the dimming apparatus at a predetermined time before a first current zero-crossing point, to cause current to flow from a body diode (1131) of the first field effect transistor (113) before the first current zero-crossing point;

during a positive half-cycle of a waveform output by a main AC power supply of the load circuit, outputting (320) a second turn-off signal to turn off a second field effect transistor (114) of the dimming apparatus at a predetermined time before a second current zero-crossing point, to cause current to flow from a body diode (1141) of the second field effect transistor (114) before the second current zero-crossing point; and

outputting (330) a dimming control signal from a dimming signal output port to control on-off states of the first field effect transistor (113) and the second field effect transistor (114).

7. The method of claim 6, wherein outputting a dimming control signal from a dimming signal output port comprises:

changing the dimming control signal to a low-level signal at a current zero-crossing point of the main AC power supply to turn off the first field effect transistor (113) and the second field effect transistor (114).

8. The method of one of claims 6-7, wherein outputting the first turn-off signal comprises:

outputting a first turn-off signal at a high level at the predetermined time before the first current zero-crossing point, to turn off the first field effect transistor (113) by changing an electrical signal acting on a gate of the first field effect transistor (113) to a low-level signal through a first triode (122).

9. The method of one of claims 6-8, wherein outputting the second turn-off signal comprises:

outputting a second turn-off signal at a high level at the predetermined time before the second current zero-crossing point, to turn off the second field effect transistor (114) by changing an electrical signal act-

ing on a gate of the second field effect transistor (114) to a low-level signal through a second triode (132).

10. The method any of claims 6-9, further comprising:

obtaining a current zero-crossing point from a zero-crossing detection circuit; and outputting at least the dimming control signal based on a detection signal of the zero-crossing detection circuit relating to the current zero-crossing point.

11. A dimming apparatus comprises:

a first field effect transistor (113) and a second field effect transistor (114) connected in series in a load circuit controlled by the dimming apparatus and respectively comprising a gate, a source and a drain, the sources of the first field effect transistor (113) and the second field effect transistor (114) being connected; and the control circuit (100) any of claims 1-5, coupled to the first field effect transistor (113) and the second field effect transistor (114).

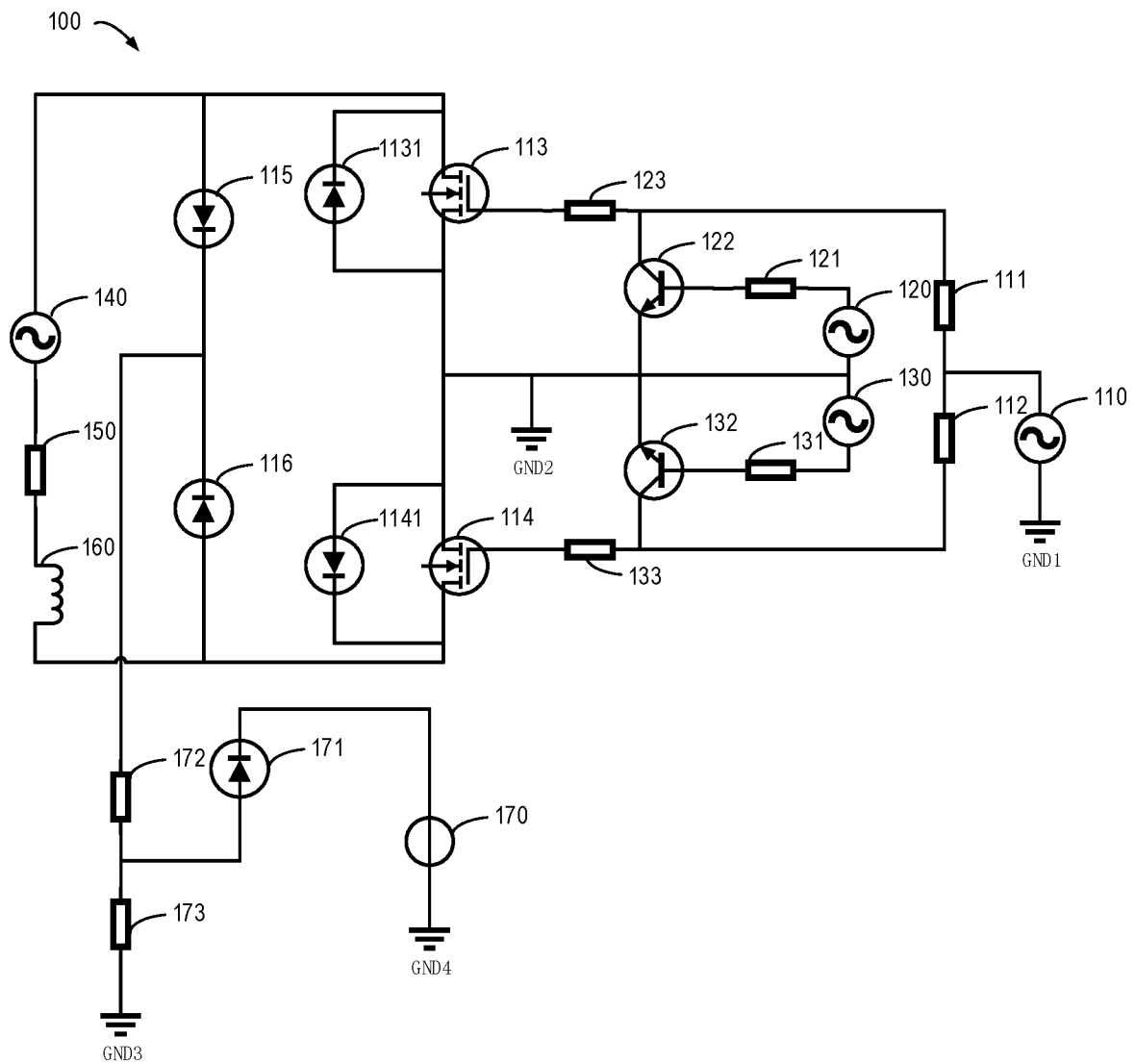


FIG. 1

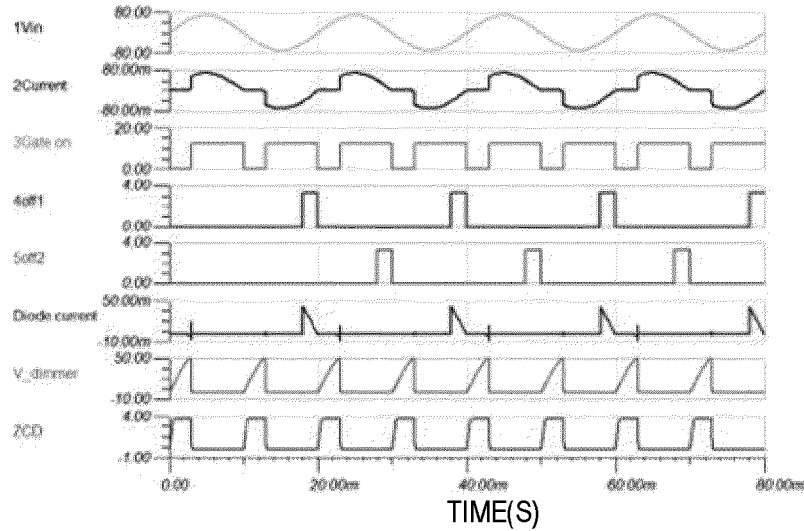


FIG. 2

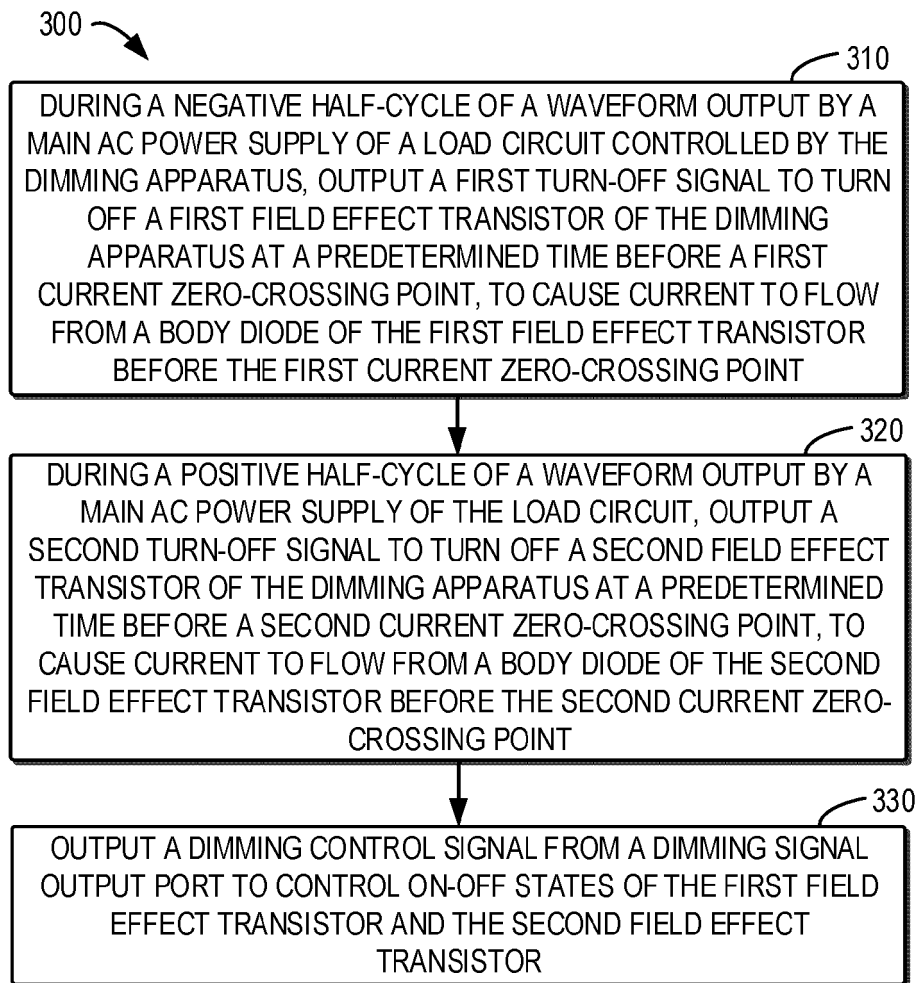


FIG. 3

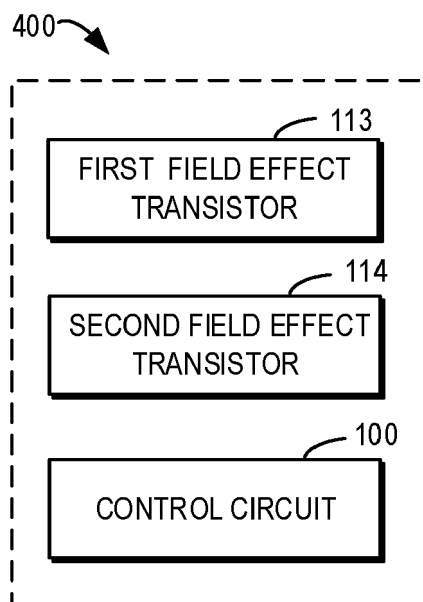


FIG. 4



EUROPEAN SEARCH REPORT

Application Number

EP 24 18 7403

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 10 158 300 B2 (LUTRON ELECTRONICS CO [US]) 18 December 2018 (2018-12-18) * columns 1,11,39; figures 13,17 * -----	1-11	INV. H05B39/04 H05B45/10
A	EP 3 307 026 A1 (PANASONIC IP MAN CO LTD [JP]) 11 April 2018 (2018-04-11) * abstract; figures 1,2 * -----	1-11	
			TECHNICAL FIELDS SEARCHED (IPC)
			H05B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		18 November 2024	Boudet, Joachim
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 24 18 7403

18-11-2024

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
US 10158300	B2	18-12-2018	CN	103931276 A	16-07-2014
			CN	104602423 A	06-05-2015
			EP	2756738 A1	23-07-2014
			EP	2919563 A1	16-09-2015
			EP	4093156 A1	23-11-2022
			US	2012230073 A1	13-09-2012
			US	2014103827 A1	17-04-2014
			US	2015108913 A1	23-04-2015
			US	2015146465 A1	28-05-2015
			US	2016233784 A1	11-08-2016
			US	2018131288 A1	10-05-2018
			US	2019081569 A1	14-03-2019
			US	2019081570 A1	14-03-2019
			US	2020067419 A1	27-02-2020
			US	2021211062 A1	08-07-2021
			US	2021234470 A1	29-07-2021
			US	2023232510 A1	20-07-2023
			US	2024114605 A1	04-04-2024
			WO	2013040136 A1	21-03-2013

EP 3307026	A1	11-04-2018	CN	107683631 A	09-02-2018
			CN	113271699 A	17-08-2021
			EP	3307026 A1	11-04-2018
			ES	2849803 T3	23-08-2021
			JP	6218101 B2	25-10-2017
			JP	6712767 B2	24-06-2020
			JP	6876949 B2	26-05-2021
			JP	7149635 B2	07-10-2022
			JP	7336714 B2	01-09-2023
			JP	2017212235 A	30-11-2017
			JP	2020129553 A	27-08-2020
			JP	2021103696 A	15-07-2021
			JP	2022168285 A	04-11-2022
			JP	2023133531 A	22-09-2023
			JP WO	2016199368 A1	13-07-2017
			KR	20180004781 A	12-01-2018
			TW	201722206 A	16-06-2017
			US	2018153021 A1	31-05-2018
			US	2019090326 A1	21-03-2019
			US	2020221556 A1	09-07-2020
WO	2016199368 A1	15-12-2016			

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 202310840272 [0001]