



EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
11.08.2021 Bulletin 2021/32

(51) Int Cl.:
H05B 45/355 (2020.01) **H05B 45/347** (2020.01)
H05B 45/14 (2020.01)

(21) Application number: **20751466.2**

(86) International application number:
PCT/CN2020/094377

(22) Date of filing: **04.06.2020**

(87) International publication number:
WO 2021/128743 (01.07.2021 Gazette 2021/26)

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(30) Priority: **23.12.2019 CN 201911339911**

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(54) **LED CONSTANT CURRENT DRIVE SYSTEM AND METHOD**

(57) The present disclosure provides an LED constant current drive system and method, including: a constant current control module, connected with a negative electrode of the LED load; a storage capacitor, which discharges to the LED load when the bus voltage is less than a voltage of the storage capacitor; a discharge voltage detection module, which obtains a control signal by determining a discharge voltage of the storage capacitor based on the negative electrode voltage of the LED load; a bus voltage detection module, which obtains a first detection voltage by detecting the bus voltage; a charge current control module, which adjusts charge voltage of the storage capacitor based on the control signal and the first detection voltage. when the bus voltage is less than the turn-on voltage of the LED, the storage capacitor discharges; when the bus voltage is greater than the turn-on voltage of the LED, the bus voltage supplies power to the LED load, and charges the storage capacitor; when the bus voltage is less than the voltage of the storage capacitor, the storage capacitor discharges. The present disclosure balances the power factor and system efficiency while ensuring that the output LED has no strobing.

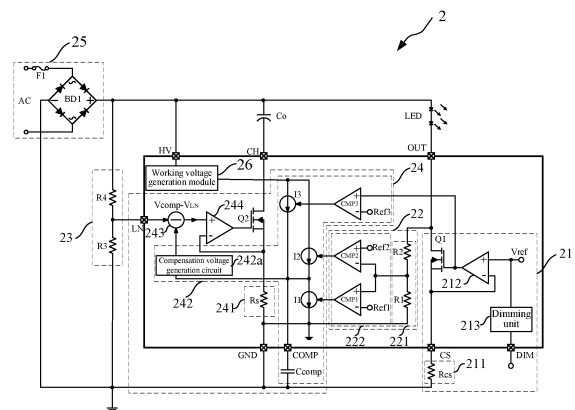


FIG 4

Description

Technical Field

[0001] The present disclosure relates to the field of system design, in particular, to an LED constant current drive system and a method thereof.

Background

[0002] Normally, the overall efficiency of a single-segment linear LED driver is determined by the LED turn-on voltage and the input voltage, satisfying:

$$Eff = \frac{V_{LED}}{V_{IN}},$$

where V_{LED} is the LED turn-on voltage and V_{IN} is the input voltage.

[0003] FIG. 1 shows a common single-segment linear LED drive structure 1. An alternating current input voltage AC IN is converted to an input voltage V_{IN} by a rectification module 11. A positive electrode of the LEDs connected in series is connected to the output terminal of the rectification module 11. A negative electrode of the LEDs connected in series is connected to a constant current control chip 12. The sampling terminal of the constant current control chip 12 is grounded via a sampling resistor 13. An adjustable module 14 is connected in parallel to the rectification module 11. Since the number of LEDs connected in series is fixed, when the input voltage V_{IN} exceeds the LED forward voltage drop V_{LED} , the excess voltage is borne by a constant current control transistor (provided in the constant current control chip 12, not shown in the figure) under the LED. $V_{IN} - V_{LED}$ is the voltage on the constant current control transistor. The higher the input voltage V_{IN} , the lower the system efficiency Eff. An electrolytic capacitor C in the adjustable module 14 can store energy, thereby ensuring that the output LED has no strobing. However, the power factor PF of the system will be low.

[0004] To improve the power factor PF, a switch transistor may be connected in series under the input electrolytic capacitor C to control the charge voltage of the electrolytic capacitor C and turn off at a high voltage, such that the voltage on the electrolytic capacitor C decreases, thereby expanding the turn-on angle of the input current to obtain a higher power factor PF. FIG. 2 is an LED drive with an external switch transistor, and a switch transistor N1 is connected in series with the lower plate of the electrolytic capacitor C. FIG. 3 is an LED drive with a built-in switch transistor, and a switch transistor is located inside the constant current control chip 12, which is not shown in the figure. The schemes shown in FIG. 2 and FIG. 3 only make a simple on-off switching operation for the input voltage V_{IN} , that is, only on or off. The system can only have high efficiency or high power factor. That is, the best combination cannot be achieved.

[0005] Therefore, how to balance the efficiency and power factor in LED control has become an urgent technical problem for the skilled in the art.

Summary

[0006] The present disclosure provides an LED constant current drive system and a method thereof, to balance the efficiency and power factor.

[0007] The present disclosure provides an LED constant current drive system, including at least:

an LED load, a positive electrode of the LED load is connected with a bus voltage;
a constant current control module, connected with a negative electrode of the LED load to perform constant current control on the LED load;
a storage capacitor, an upper plate of the storage capacitor is connected with the positive electrode of the LED load; the storage capacitor discharges to the LED load when the bus voltage is less than a voltage on the storage capacitor;
a discharge voltage detection module, connected with the negative electrode of the LED load, and obtaining a control signal by determining the discharge voltage of the storage capacitor based on the negative electrode voltage of the LED load;
a bus voltage detection module, obtaining a first detection voltage by detecting the bus voltage; and
a charge current control module, connected with the output terminals of the discharge voltage detection module and the bus voltage detection module, and a lower plate of the storage capacitor; adjusting the charge voltage of the storage capacitor based on the control signal and the first detection voltage.

[0008] The present disclosure provides an LED constant current drive method, including at least:

discharging, by a storage capacitor, to an LED load, and performing, by the storage capacitor, constant current control on the LED load based on the constant current control module when the bus voltage is less than the turn-on voltage of the LED;
supplying power, by the bus voltage, to the LED load, and performing, by the bus voltage, constant current control on the LED load based on the constant current control module when the bus voltage is greater than the turn-on voltage of the LED; at the same time, charging, by the bus voltage, the storage capacitor;
discharging, by the storage capacitor, to the LED load and performing constant current control on the LED load based on the constant current control module when the bus voltage is less than the voltage of the storage capacitor.

[0009] The details of one or more embodiments of the

present disclosure will be described in the ensuing drawings description. Other features, objects, and advantages of the present disclosure will be apparent from the description and drawings, and from the claims.

Brief Description of the Drawings

[0010]

FIG. 1 is a schematic diagram of a single-segment linear LED drive structure in the traditional technology.

FIG. 2 is a schematic diagram of an LED drive with an external switch transistor in the traditional technology.

FIG. 3 is a schematic diagram of an LED drive with a built-in switch transistor in the traditional technology.

FIG. 4 is a schematic diagram of an LED constant current drive system of the present disclosure.

FIG. 5 is a waveform diagram of the LED constant current drive method of the present disclosure.

Detailed Description of the Preferred Embodiments

[0011] The embodiments of the present disclosure will be described below through exemplary embodiments. Those skilled in the art can easily understand other advantages and effects of the present disclosure according to contents disclosed by the specification. The present disclosure can also be implemented or applied through other different exemplary embodiments. Various modifications or changes can also be made to all details in the specification based on different points of view and applications without departing from the spirit of the present disclosure.

[0012] Referring to FIGs 4-5. It needs to be stated that the drawings provided in the following embodiments are just used for schematically describing the basic concept of the present disclosure, thus only illustrating components only related to the present disclosure and are not drawn according to the numbers, shapes and sizes of components during actual implementation, the configuration, number and scale of each component during the actual implementation thereof may be freely changed, and the component layout configuration thereof may be more complex.

Embodiment 1

[0013] As shown in FIG. 4, this Embodiment provides an LED constant current drive system 2, which includes: an LED load, a constant current control module 21, a storage capacitor Co, a discharge voltage detection module 22, a bus voltage detection module 23 and a charge current control module 24.

[0014] As shown in FIG. 4, the LED load is connected with the bus voltage Vin.

[0015] Specifically, in this Embodiment, the bus voltage Vin is provided by the rectification module 25, and the rectification module 25 rectifies the alternating current power supply AC to obtain the bus voltage Vin. The rectification module 25 includes a rectifier bridge structure BD1 and a fuse F1. The rectifier bridge structure BD1 includes two sets of diodes connected in parallel. Each diode set includes two diodes connected in series. The alternating current power supply AC is connected between the two diodes of each diode set after passing through the fuse F1. The bus voltage Vin is a rectified voltage after sinusoidal voltage rectification.

[0016] Specifically, the positive electrode of the LED load is connected with the output terminal of the rectification module 25. The LED load includes a plurality of LEDs connected in series. The LED load may also be a series-parallel structure of a plurality of LEDs, and is not limited to this embodiment. When the voltage across the LED load reaches the turn-on voltage, the LEDs in the LED load light up and play a role in lighting.

[0017] As shown in FIG. 4, the constant current control module 21 is connected with the negative electrode of the LED load, to perform constant current control on the LED load.

[0018] Specifically, in this embodiment, the constant current control module 21 includes: a first power switch transistor Q1, a first sampling unit 211, and a first operational amplification unit 212. The drain of the first power switch transistor Q1 is connected with the negative electrode of the LED load, the source of the first power switch transistor Q1 is grounded via the first sampling unit 211, and the gate of the first power switch transistor Q1 is connected with the output terminal of the first operational amplification unit 212. As an example, in this embodiment, the first sampling unit 211 includes a first sampling resistor Rcs, one terminal of the first sampling resistor Rcs is connected with the source of the first power switch transistor Q1, and the other terminal of the first sampling resistor Rcs is grounded. The inverting input terminal of the first operational amplification unit 212 is connected with the source of the first power switch transistor Q1, the non-inverting input terminal of the first operational amplification unit 212 is connected with the reference voltage Vref, and the output terminal of the first operational amplification unit 212 is connected to the gate of the first power switch transistor Q1. The first operational amplification unit 212 compares the sampling voltage of the source of the first power switch transistor Q1 with the reference voltage Vref, to control the current flowing through the LED load, thereby achieving the constant current control.

[0019] It should be noted that the reference voltage Vref is an internal fixed value or externally provided. When the reference voltage Vref is an internal fixed value, the output current of the LED load can be adjusted by changing the resistance value of the first sampling resistor Rcs. The connection relationship between the input terminal and the output terminal of the first operational amplification unit 212 can be adjusted, and the same

logic relationship can be achieved by adding an inverter, which is not limited to this embodiment.

[0020] As an implementation manner of the present disclosure, the constant current control module 21 further includes a dimming unit 213, an input terminal of the dimming unit 213 receives a dimming control signal DIM, and an output terminal of the dimming unit 213 is connected with the non-inverting input terminal of the first operational amplification unit 212. The reference voltage V_{ref} is adjusted based on the dimming control signal DIM, thereby achieving dimming control. The dimming control signal DIM includes, but is not limited to, an analog signal or a pulse width modulation signal (PWM), which will not be described in detail here.

[0021] It should be noted that any system structure that can implement constant current control is applicable to the present disclosure, and is not limited to this embodiment.

[0022] As shown in FIG. 4, the upper plate of the storage capacitor C_o is connected to the positive electrode of the LED load. When the bus voltage V_{in} is less than the voltage V_{Co} on the storage capacitor C_o , the storage capacitor C_o discharges to the LED load.

[0023] Specifically, the upper plate of the storage capacitor C_o is connected between the rectification module 25 and the LED load, and the lower plate is connected with the charge current control module 24. When the bus voltage V_{in} is greater than the voltage V_{Co} on the storage capacitor C_o , the bus voltage V_{in} charges the storage capacitor C_o , and at the same time, the bus voltage V_{in} supplies power to the LED load. When the bus voltage V_{in} is less than the voltage V_{Co} on the storage capacitor C_o , the storage capacitor C_o supplies power to the LED load.

[0024] As shown in FIG. 4, the discharge voltage detection module 22 is connected with the negative electrode of the LED load, and the discharge voltage of the storage capacitor C_o is determined based on the negative electrode voltage of the LED load to obtain a control signal.

[0025] Specifically, the discharge voltage detection module 22 includes: a first detection unit 221 and a comparison unit 222. The detection unit 221 is connected with the negative electrode of the LED load, and detects the negative electrode voltage of the LED load to obtain a second detection voltage. The comparison unit 222 is connected with the output terminal of the detection unit 221, and the discharge voltage of the storage capacitor C_o is determined based on the second detection voltage.

[0026] More specifically, in this embodiment, the detection unit 221 includes a first resistor R1 and a second resistor R2. The first resistor R1 and the second resistor R2 are connected in series between the negative electrode of the LED load and ground, and the second detection voltage is obtained by dividing the voltage.

[0027] More specifically, the comparison unit 222 includes a first comparator CMP1 and a second comparator CMP2. The non-inverting input terminal of the first

comparator CMP1 is connected with the second detection voltage, and the inverting input terminal is connected with the first preset voltage Ref1, to output a first control signal. When the second detection voltage is greater than the first preset voltage Ref1, the first comparator CMP1 outputs a high level, and the first control signal is valid. When the second detection voltage is less than the first preset voltage Ref1, the first comparator CMP1 outputs a low level, and the first control signal is invalid. The inverting input terminal of the second comparator CMP2 is connected with the second detection voltage, and the non-inverting input terminal is connected with the second preset voltage Ref2, to output a second control signal. When the second detection voltage is greater than the second preset voltage Ref2, the second comparator CMP2 outputs a low level, and the second control signal is invalid. When the second detection voltage is less than the second preset voltage Ref2, the second comparator CMP2 outputs a high level, and the second control signal is valid. The first preset voltage Ref1 is greater than the second preset voltage Ref2.

[0028] It should be noted that the connection relationship between the input terminals and output terminals of the first comparator CMP1 and the second comparator CMP2 can be adjusted, and the same logic relationship can be achieved by adding an inverter, which is not limited to this embodiment.

[0029] As shown in FIG. 4, the bus voltage detection module 23 is connected with the bus voltage V_{in} , and detects the bus voltage V_{in} to obtain a first detection voltage V_{LN} .

[0030] Specifically, in this embodiment, the bus voltage detection module 23 includes a third resistor R3 and a fourth resistor R4. The third resistor R3 and the fourth resistor R4 are connected in series between the output terminal of the rectification module 25 and ground, and the first detection voltage V_{LN} is obtained by dividing the voltage. The bus voltage detection module 23 may be integrated inside the chip, or may be provided outside the chip.

[0031] As shown in FIG. 4, the charge current control module 24 is connected with the output terminals of the discharge voltage detection module 22 and the bus voltage detection module 23, and the lower plate of the storage capacitor C_o . The charge current of the storage capacitor C_o is adjusted based on the control signal and the first detection voltage V_{LN} .

[0032] Specifically, the charge current control module 24 includes a second power switch transistor Q2, a second sampling unit 241, a compensation unit 242, a subtraction unit 243, and a second operational amplification unit 244.

[0033] More specifically, the drain of the second power switch transistor Q2 is connected with the lower plate of the storage capacitor C_o , the source of the second power switch transistor Q2 is grounded via the second sampling unit 241, and the gate of the second power switch transistor Q2 is connected with the output terminal of the

second operational amplification unit 244, to adjust the charge current of the storage capacitor Co. As an example, in this embodiment, the second sampling unit 241 includes a second sampling resistor Rcs, one terminal of the second sampling resistor Rcs is connected with the source of the second power switch Q2, and the other terminal of the second sampling resistor Rcs is grounded.

[0034] More specifically, the input terminal of the compensation unit 242 is connected with the discharge voltage detection module 22 and generates a corresponding compensation voltage Vcomp based on the output signal of the discharge voltage detection module 22. In this embodiment, the compensation unit 242 includes a compensation voltage generation circuit 242a, a compensation capacitor Ccomp, a first current source 11, and a second current source 12. The compensation voltage generation circuit 242a is connected with the upper plate of the compensation capacitor Ccomp, and the lower plate of the compensation capacitor Ccomp is grounded. One terminal of the first current source 11 is grounded, the other terminal of the first current source 11 is connected with the upper plate of the compensation capacitor Ccomp, and the control terminal of the first current source is connected with the first control signal. When the first control signal is valid, the first current source 11 is turned on and discharges to the compensation capacitor Ccomp. One terminal of the second current source 12 is connected with the upper plate of the compensation capacitor Ccomp, the other terminal of the second current source 12 is connected with the working voltage VDD, and the control terminal of the second current source 12 is connected with the second control signal. When the second control signal is valid, the second current source 12 is turned on and charges the compensation capacitor Ccomp. The value of the compensation voltage Vcomp is adjusted based on the charging and discharging of the first current source 11 and the second current source 12. The compensation capacitor Ccomp may be provided outside the chip, or may be integrated into the chip using digital filtering technology to reduce peripheral components and simplify the system.

[0035] More specifically, the subtraction unit 243 is connected with the compensation unit 242 and the output terminal of the bus voltage detection module 23, to obtain the difference between the compensation voltage Vcomp and the first detection voltage V_{LN} .

[0036] More specifically, the inverting input terminal of the second operational amplification unit 244 is connected with the source of the second power switch transistor Q2, the non-inverting input terminal of the second operational amplification unit 244 is connected with the output terminal of the subtraction unit 243, and the output terminal of the second operational amplification unit 244 is connected with the gate of the second power switch transistor Q2. The second operational amplification unit 244 compares the sampling voltage of the source of the second power switch transistor Q2 with the output voltage of the subtraction unit 243, to adjust the charge current

of the storage capacitor Co.

[0037] It should be noted that the connection relationship between the input terminal and the output terminal of the second operational amplification unit 244 can be adjusted, and the same logic relationship can be achieved by adding an inverter, which is not limited to this embodiment.

[0038] As an implementation manner of the present disclosure, the compensation unit 242 further includes a third comparator CMP3 and a third current source 13. The non-inverting input terminal of the third comparator CMP3 is connected with the gate of the first power switch transistor Q1, and the inverting input terminal of the third comparator CMP3 is connected with the third preset voltage Ref3, to output a third control signal. When the gate voltage of the first power switch transistor Q1 is greater than the third preset voltage Ref3, a high level is output, and the third control signal is valid. One terminal of the third current source 13 is connected with the upper plate of the compensation capacitor Ccomp, the other terminal of the third current source 13 is connected with the working voltage VDD, and the control terminal of the third current source 13 is connected with the output terminal of the third comparator CMP3. When the third control signal is valid, the third current source is turned on.

[0039] It should be noted that the connection relationship between the input terminal and output terminal of the third comparator CMP3 can be adjusted, and the same logic relationship can be achieved by adding an inverter, which is not limited to this embodiment.

[0040] As an implementation manner of the present disclosure, the LED constant current drive system further includes a working voltage generation module 26. The working voltage generation module 26 is connected with the bus voltage Vin. The working voltage VDD is provided for the LED constant current drive system based on the bus voltage Vin.

[0041] The LED constant current drive system of the present disclosure eliminates LED strobing based on constant current control, supplies power to the LED through the storage capacitor Co during the valley period of the bus voltage, and reduces the charge current of the storage capacitor Co when the bus voltage is too high. Therefore, the power factor and system efficiency are balanced by the LED constant current drive system of the present disclosure.

Embodiment 2

[0042] As shown in FIGs. 4 and 5, this embodiment provides an LED constant current drive method. In this embodiment, the LED constant current drive method of the present disclosure is implemented based on the LED constant current drive system of Embodiment 1. In actual use, any hardware circuit or software code that can implement the LED constant current drive method of the present disclosure is applicable. The LED constant current drive method includes:

[0043] When the bus voltage V_{in} is less than the turn-on voltage of the LED, the storage capacitor C_o discharges to the LED load and performs constant current control on the LED load based on the constant current control module 21.

[0044] Specifically, during normal operation, the voltage on the storage capacitor C_o would not drop to a very low level, so the chip can be internally powered during the valley period of the bus voltage V_{in} . When the bus voltage V_{in} is less than the turn-on voltage of the LED load, the bus voltage V_{in} is insufficient to turn on the LED load. At this time, the storage capacitor C_o discharges to the LED load to light up the LED load, and the constant current control module 21 performs constant current control on the current flowing through the LED load.

[0045] Specifically, the constant current control module 21 detects the source voltage of the first power switch transistor Q1 and compares the source voltage of the first power switch transistor Q1 with the reference voltage V_{ref} , to control the gate of the first power switch Q1 based on the comparison result, thereby achieving the constant current control and assuring that the current flowing through the LED load is constant, so as to eliminate the strobing.

[0046] It should be noted that the reference voltage V_{ref} is an internal preset value. The output current of the LED can be adjusted by changing the resistance value of the first sampling resistor R_{cs} . The reference voltage V_{ref} is an adjustable value provided externally.

[0047] As an implementation manner of the present disclosure, the constant current control module 21 further adjusts the value of the reference voltage V_{ref} based on the dimming control signal DIM, thereby achieving dimming control. The dimming control signal DIM includes, but is not limited to, an analog signal or a PWM signal.

[0048] When the bus voltage V_{in} is greater than the turn-on voltage of the LED, the bus voltage V_{in} supplies power to the LED load, and performs constant current control on the LED load based on the constant current control module 21. At the same time, the bus voltage V_{in} charges the storage capacitor C_o .

[0049] Specifically, the bus voltage V_{in} gradually increases. When the bus voltage V_{in} is greater than the turn-on voltage of the LED, the bus voltage V_{in} supplies power to the LED load, and charges the storage capacitor C_o . The charge current of the storage capacitor C_o is controlled by the second power switch transistor Q2, the second operational amplification unit 244 and the second sampling resistor R_s , thereby expanding the turn-on angle of the input current to improve the power factor.

[0050] Specifically, in this embodiment, the charge current of the storage capacitor is adjusted based on the negative electrode voltage of the LED load and the bus voltage V_{in} . The bus voltage detection module 23 detects the bus voltage V_{in} , and reduces the charge current of the storage capacitor C_o to zero when the bus voltage V_{in} is too high, thereby reducing the loss of the second power switch transistor Q2 and improving the overall ef-

ficiency of the system. To ensure the maximum system efficiency, the discharge voltage of the storage capacitor C_o cannot be too high. To keep the output LED current constant, the discharge voltage of the storage capacitor C_o cannot be too low. In this embodiment, the discharge voltage of the storage capacitor C_o is determined by the LED negative electrode voltage ($V_{OUT} = V_{in} - V_{LED}$). More specifically, the LED negative electrode voltage is detected by the detection unit 221. When the detected voltage is higher than the first preset voltage $Ref1$, it indicates that the discharge voltage of the storage capacitor C_o is high. The first comparator CMP1 controls the turn-on of the first constant current source 11, discharges the compensation capacitor C_{comp} and reduces the compensation voltage V_{comp} , to reduce the charge current of the storage capacitor C_o , so as to reduce the discharge voltage of the storage capacitor C_o . When the detected voltage is lower than the second preset voltage $Ref2$, it indicates that the discharge voltage of the storage capacitor C_o is low. The second comparator CMP2 controls the turn-on of the second constant current source 12, charges the compensation capacitor C_{comp} and increases the compensation voltage V_{comp} , to increase the charge current of the storage capacitor C_o , so as to increase the discharge voltage of the storage capacitor C_o . In order to optimize the system performance, $Ref1 > Ref2$. After the loop adjustment of the compensation unit 242, it is ensured that after the LED current is constant, the lowest level of the LED negative electrode voltage would not be too high to cause the loss of system efficiency.

[0051] As an implementation manner of the present disclosure, to filter out the power frequency ripple, the compensation capacitor C_{comp} is large, and the loop response is slow. When the output voltage is too low, the LED current will drop. At this time, the gate voltage of the first power switch transistor Q1 would rise to a high level (especially when the compensation voltage V_{comp} is low immediately after turning-on). When the third comparator CMP3 detects that the gate voltage of the first power switch transistor Q1 exceeds the third preset voltage $Ref3$, the third constant current source 13 is controlled to be turned on (in this embodiment, the current flowing through the third current source is greater than the current flowing through the second current source, $I1 > I2$), the compensation voltage V_{comp} is rapidly increased, the charge current of the storage capacitor C_o is enhanced, and the discharge voltage of the storage capacitor C_o is quickly increased.

[0052] When the bus voltage V_{in} is less than the voltage of the storage capacitor C_o , the storage capacitor C_o discharges to the LED load and performs constant current control on the LED load based on the constant current control module 21.

[0053] Specifically, the bus voltage V_{in} gradually decreases after reaching a peak value. When the bus voltage V_{in} is less than the voltage of the storage capacitor C_o , the storage capacitor C_o discharges to the LED load

until the bus voltage V_{in} is again greater than the turn-on voltage of the LED or the voltage of the storage capacitor C_o is less than the turn-on voltage of the LED.

[0054] FIG. 5 shows the operational waveform diagram of the LED constant current drive method of the present disclosure:

[0055] As shown in FIG. 5, at time t_0 , the bus voltage V_{in} rises from zero, $V_{in} < V_{LED}$, V_{LED} is the turn-on voltage of the LED load. At this time, the storage capacitor C_o discharges to the LED load. For the voltage V_{Co} on the storage capacitor C_o , the lowest voltage for discharging is V_{LED} . The current I_{Co} of the storage capacitor C_o during discharge is a constant value. The current flowing through the LED load is a constant value. The negative electrode voltage V_{LED-} of the LED load gradually decreases (the minimum value is V_{LED-}_{min}).

[0056] As shown in FIG. 5, as the bus voltage V_{in} rises, at time t_1 , the bus voltage V_{in} is greater than the turn-on voltage V_{LED} of the LED load. The bus voltage V_{in} supplies power to the LED while charging the storage capacitor C_o . The current I_{in} provided by the bus voltage V_{in} includes the charge current of the storage capacitor C_o and the constant current of the LED load. The charge current is determined jointly by the compensation voltage V_{comp} and the detection voltage of the bus voltage V_{in} . The charge current of the storage capacitor C_o generally decreases with the increase of the bus voltage V_{in} . In this embodiment, the charge current of the storage capacitor C_o decreases first and then increases. As the voltage V_{Co} of the storage capacitor C_o is charged to the highest voltage V_{Co_max} , the storage capacitor C_o stops charging. During this process, the negative electrode voltage V_{LED-} of the LED load gradually increases.

[0057] As shown in FIG. 5, the bus voltage V_{in} starts to decrease after reaching a peak value. At time t_2 , when the bus voltage V_{in} is less than the voltage V_{Co} of the storage capacitor C_o (in this embodiment, at this time, the voltage of the storage capacitor C_o is the highest voltage V_{Co_max} ; for convenience of illustration, V_{Co_max} of different power frequency periods adopts the same level), the storage capacitor C_o begins to discharge to the LED load until a power frequency cycle terminals at time t_3 . During this power frequency cycle, the shadow area of the charge current A of the storage capacitor C_o is equal to the shadow area of the discharge current B of the storage capacitor C_o in the figure, C is the shadow area of the current provided by the bus voltage to the LED.

[0058] As shown in FIG. 5, times t_4 - t_7 and times t_8 - t_{11} are power frequency cycles of different bus voltages. The charge current changes with the change of bus voltage. At high input voltage, the minimum charge current can be reduced to zero, and after the loop adjustment, the minimum value of the negative electrode voltage of the LED load is V_{LED-}_{min} and remains unchanged, which keeps the output LED current constant while minimizing the loss of the second power switch transistor Q_2 .

[0059] As shown in FIG. 5, the present disclosure re-

duces the charge current of the storage capacitor C_o when the bus voltage V_{in} is high through detecting the bus voltage V_{in} , thereby reducing the charge power consumption of the second power switch transistor Q_2 and improving the overall efficiency of the system. Regulating the voltage division ratio of the third resistor R_3 and the fourth resistor R_4 can adjust the high-voltage drop current. The greater the peak value of the bus voltage V_{in} , the smaller the peak value of the charge current of the storage capacitor C_o , thereby obtaining a compromise between system efficiency and power factor.

[0060] In summary, the present disclosure provides an LED constant current drive system and method, including: an LED load, a positive electrode of the LED load is connected with a bus voltage; a constant current control module, which is connected with a negative electrode of the LED load to perform constant current control on the LED load; a storage capacitor, an upper plate of the storage capacitor is connected with the positive electrode of the LED load; the storage capacitor discharges to the LED load when the bus voltage is less than a voltage on the storage capacitor; a discharge voltage detection module, which is connected with the negative electrode of the LED load, and obtains a control signal by judging the discharge voltage of the storage capacitor based on the negative electrode voltage of the LED load; a bus voltage detection module, which obtains a first detection voltage by detecting the bus voltage; a charge current control module, which is connected to the output terminal of the discharge voltage detection module and a lower plate of the storage capacitor; the charge current control module adjusts the charge current of the storage capacitor based on the control signal and the first detection voltage. When the bus voltage is less than the turn-on voltage of the LED, the storage capacitor discharges to the LED load and performs constant current control on the LED load based on the constant current control module. When the bus voltage is greater than the turn-on voltage of the LED, the bus voltage supplies power to the LED load, and performs constant current control on the LED load based on the constant current control module. At the same time, the bus voltage charges the storage capacitor. When the bus voltage is less than the voltage of the storage capacitor, the storage capacitor discharges to the LED load and performs constant current control on the LED load based on the constant current control module. The LED constant current drive system and method of the present disclosure detects the negative electrode voltage of the LED to control the charge current of the storage capacitor, and minimizes the loss of the constant current power switch transistor while ensuring that the output LED has no strobing; the gate voltage of the constant current power switch transistor is detected, to speed up the loop response speed and ensure a quick start; the storage capacitor can supply power to the LED when the input voltage is during the valley period; at the same time, when the input voltage is high, the charge current of the storage capacitor is reduced.

Therefore, the power factor and system efficiency are balanced. Moreover, the peripheral system of the LED constant current drive system of the present disclosure is the most simplified, and the system cost is low. Therefore, the present disclosure effectively overcomes various shortcomings and has high industrial utilization value.

[0061] The above-described embodiments are merely illustrative of the principles of the disclosure and its effects, and are not intended to limit the disclosure. Modifications or variations of the above-described embodiments may be made by those skilled in the art without departing from the spirit and scope of the disclosure. Therefore, all equivalent modifications or changes made by those who have common knowledge in the art without departing from the spirit and technical concept disclosed by the present disclosure shall be still covered by the claims of the present disclosure.

Claims

1. An LED constant current drive system, comprising at least:

an LED load, a positive electrode of the LED load is connected with a bus voltage;
 a constant current control module, connected with a negative electrode of the LED load to perform constant current control on the LED load;
 a storage capacitor, wherein an upper plate of the storage capacitor is connected with a positive electrode of the LED load, to discharge to the LED load when the bus voltage is less than a voltage on the storage capacitor;
 a discharge voltage detection module, connected with the negative electrode of the LED load, and obtaining a control signal by determining a discharge voltage of the storage capacitor based on a negative electrode voltage of the LED load;
 a bus voltage detection module, obtaining a first detection voltage by detecting the bus voltage; and
 a charge current control module, connected with output terminals of the discharge voltage detection module and the bus voltage detection module, and a lower plate of the storage capacitor, and adjusting a charge current of the storage capacitor based on the control signal and the first detection voltage.

2. The LED constant current drive system according to claim 1, wherein the constant current control module comprises a first power switch transistor, a first sampling unit, and a first operational amplification unit; a drain of the first power switch transistor is connected with the negative electrode of the LED load, a

source of the first power switch is grounded via the first sampling unit;

an input terminal of the first operational amplification unit is respectively connected with the source of the first power switch transistor and a reference voltage, an output terminal of the first operational amplification unit is connected with a gate of the first power switch transistor, and the first operational amplification unit compares a sampling voltage with the reference voltage to control a current flowing through the LED load.

3. The LED constant current drive system according to claim 2, wherein the constant current control module further comprises a dimming unit which is connected with the first operational amplification unit, the dimming unit receives a dimming control signal and adjusts the reference voltage based on the dimming control signal to achieve a dimming control.

4. The LED constant current drive system according to claim 3, wherein the dimming control signal is an analog signal or a pulse width modulation signal.

5. The LED constant current drive system according to claim 1, wherein the discharge voltage detection module comprises a detection unit and a comparison unit;
 the detection unit is connected with the negative electrode of the LED load, and obtains a second detection voltage by detecting the negative electrode voltage of the LED load;
 the comparison unit is connected with an output terminal of the detection unit, and determines the discharge voltage of the storage capacitor based on the second detection voltage.

6. The LED constant current drive system according to claim 5, wherein the comparison unit comprises a first comparator and a second comparator; an input terminal of the first comparator is respectively connected with the second detection voltage and a first preset voltage, to output a first control signal when the second detection voltage is greater than the first preset voltage; an input terminal of the second comparator is respectively connected with the second detection voltage and a second preset voltage, to output a second control signal when the second detection voltage is less than the second preset voltage.

7. The LED constant current drive system according to claim 1, wherein the charge current control module comprises a second power switch transistor, a second sampling unit, a compensation unit, a subtraction unit, and a second operational amplification unit; a drain of the second power switch transistor is connected with the lower plate of the storage capacitor, a

a source of the second power switch transistor is grounded via the second sampling unit;
 an input terminal of the compensation unit is connected with the discharge voltage detection module and generates a corresponding compensation voltage based on an output signal of the discharge voltage detection module;
 the subtraction unit is connected with the compensation unit and the output terminal of the bus voltage detection module, to obtain a difference between the compensation voltage and the first detection voltage;
 an input terminal of the second operational amplification unit is respectively connected with an output terminal of the subtraction unit and the source of the second power switch transistor, and an output terminal of the second operational amplification unit is connected with a gate of the second power switch transistor, to adjust a charge current of the storage capacitor.

8. The LED constant current drive system according to claim 7, wherein the compensation unit comprises a compensation voltage generation circuit, a compensation capacitor, a first current source and a second current source;
 the compensation voltage generation circuit is connected with an upper plate of the compensation capacitor, and a lower plate of the compensation capacitor is grounded;
 one terminal of the first current source is grounded, the other terminal of the first current source is connected with the upper plate of the compensation capacitor;
 one terminal of the second current source is connected with the upper plate of the compensation capacitor, and the other terminal of the second current source is connected with a working voltage;
 control terminals of the first current source and the second current source are respectively connected with the output terminal of the discharge voltage detection module, and a value of the compensation voltage is adjusted based on the charging and discharging of the first current source and the second current source.
9. The LED constant current drive system according to claim 8, wherein the comparison unit further comprises a third comparator and a third current source;
 an input terminal of the third comparator is respectively connected with a gate of the power switch transistor in the constant current control module and a third preset voltage;
 one terminal of the third current source is connected with the upper plate of the compensation capacitor, the other terminal of the third current source is connected with the working voltage, and a control terminal of the third current source is connected to an output terminal of the third comparator;

the third current source is turned on when a gate voltage of the power switch transistor is greater than the third preset voltage.

10. The LED constant current drive system according to claim 1, further comprising a working voltage generation module, and the working voltage generation module is connected with the bus voltage and provides a working voltage for the LED constant current drive system based on the bus voltage.
11. An LED constant current drive method, comprising at least:
 discharging, by a storage capacitor, to an LED load, and performing, by the storage capacitor, constant current control on the LED load based on a constant current control module when a bus voltage is less than a turn-on voltage of the LED;
 supplying power, by the bus voltage, to the LED load, and performing, by the bus voltage, constant current control on the LED load based on the constant current control module when the bus voltage is greater than the turn-on voltage of the LED; at the same time, charging, by the bus voltage, the storage capacitor;
 discharging, by the storage capacitor, to the LED load and performing constant current control on the LED load based on the constant current control module when the bus voltage is less than the voltage of the storage capacitor.
12. The LED constant current drive method according to claim 11, a charge current of the storage capacitor is adjusted based on a negative electrode voltage of the LED load and the bus voltage.
13. The LED constant current drive method according to claim 12, a charge current of the storage capacitor is adjusted based on the bus voltage, the greater a peak value of the bus voltage, the smaller a peak value of the charge current of the storage capacitor.
14. The LED constant current drive method according to claim 11, a charge current of the storage capacitor is increased when a gate voltage of a power switch transistor in the constant current control module is greater than a preset voltage.
15. The LED constant current drive method according to claim 11, wherein the charge current of the storage capacitor decreases first and then increases.

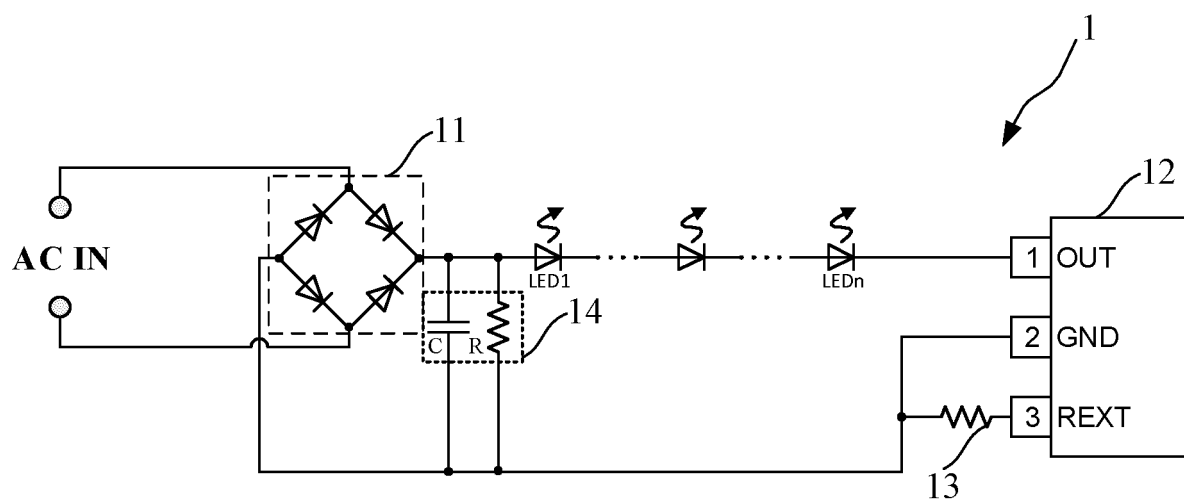


FIG. 1

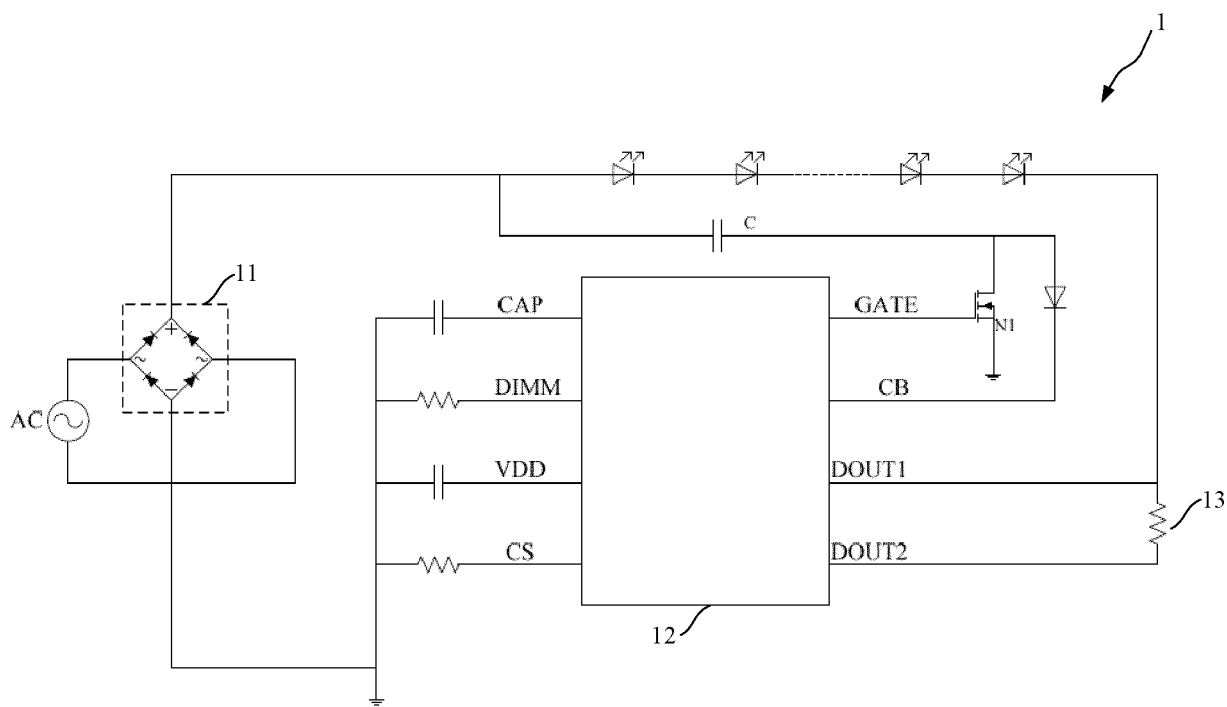


FIG. 2

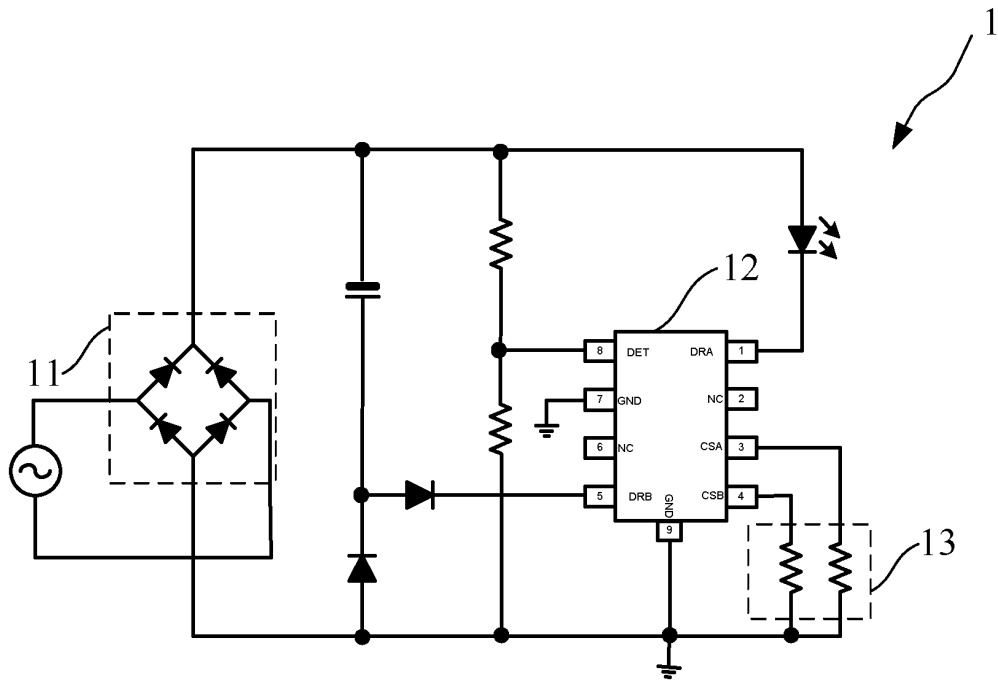


FIG. 3

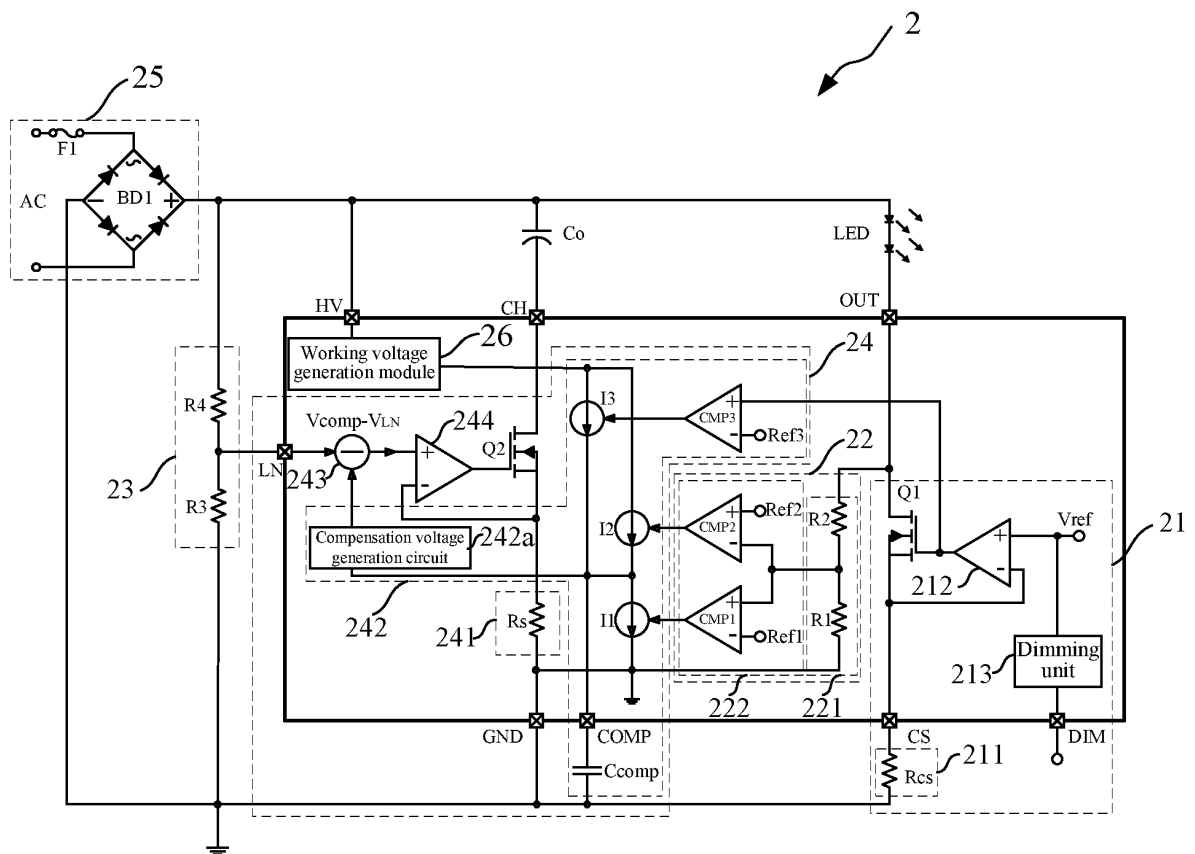


FIG. 4

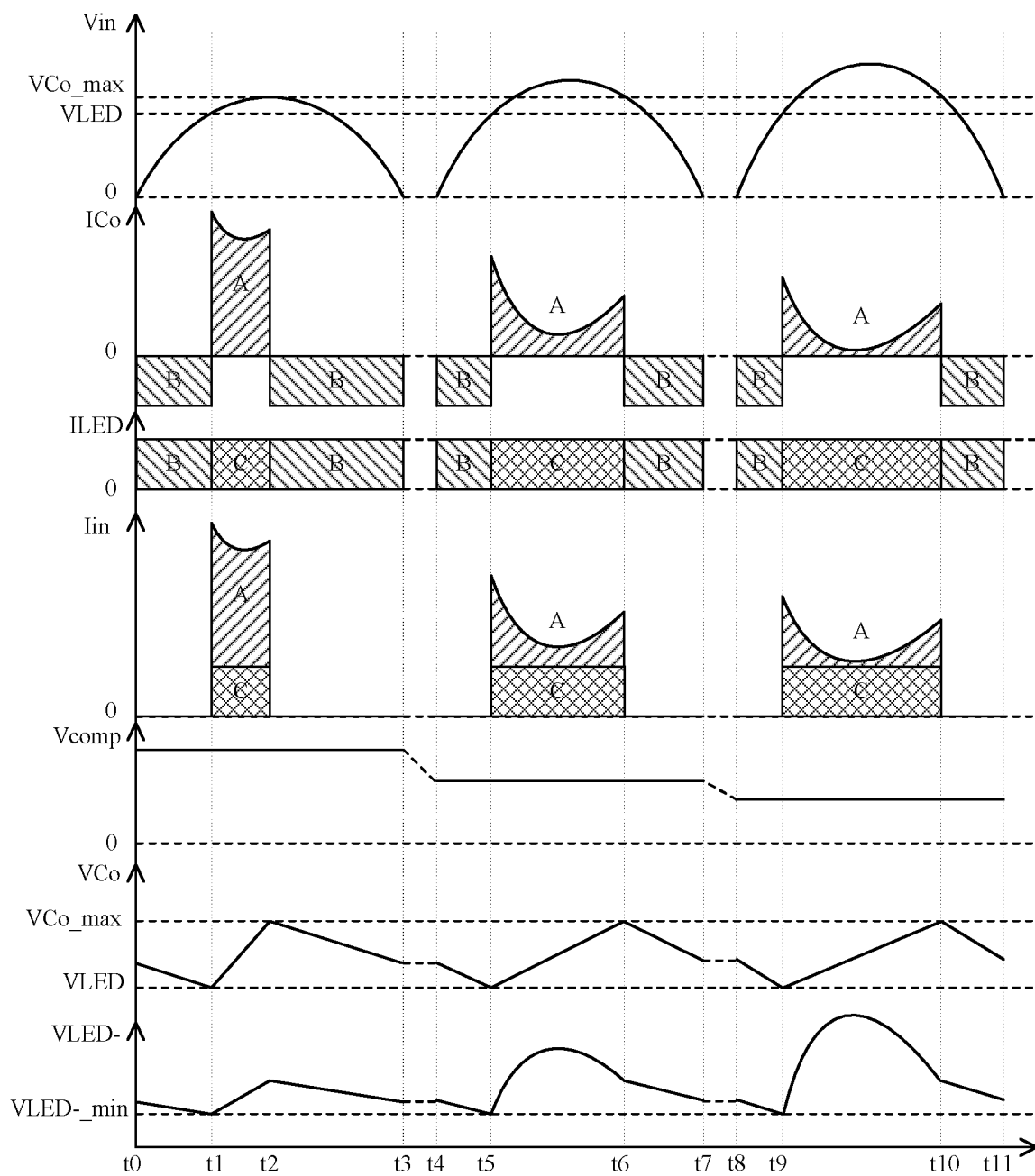


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/094377

A. CLASSIFICATION OF SUBJECT MATTER

H05B 45/345(2020.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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)

WPI, EPODOC, CNPAT, CNKI: 晟碟, 充电, 放电, 补偿, 分压, charge+, discharge+, compens+, divid+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 108966430 A (GUANGDONG UNIVERSITY OF TECHNOLOGY) 07 December 2018 (2018-12-07) description paragraphs 25-36, and figures 1, 4	1-6, 10-15
X	CN 107911907 A (SILERGY SEMICONDUCTOR TECHNOLOGY (HANGZHOU) CO., LTD.) 13 April 2018 (2018-04-13) description paragraph 75, and figure 9	1-6, 10-15
A	CN 110505733 A (SHENZHEN SANDISK SEMICONDUCTOR CO., LTD.) 26 November 2019 (2019-11-26) entire document	1-15
A	US 2019191506 A1 (SILERGY SEMICONDUCTOR TECHNOLOGY HANGZHOU LTD.) 20 June 2019 (2019-06-20) entire document	1-15
A	CN 110572897 A (SHENZHEN SANDISK SEMICONDUCTOR CO., LTD.) 13 December 2019 (2019-12-13) entire document	1-15

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

* Special categories of cited documents:	"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
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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	

Date of the actual completion of the international search

19 August 2020

Date of mailing of the international search report

31 August 2020

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2020/094377

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CN 107911907 A	13 April 2018	US 2019182918 A1	13 June 2019
		US 202000214106 A1	02 July 2020
CN 110505733 A	26 November 2019	None	
US 2019191506 A1	20 June 2019	CN 107995736 A	04 May 2018
CN 110572897 A	13 December 2019	None	

Form PCT/ISA/210 (patent family annex) (January 2015)