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(54) **TRIAC DIMMABLE LED DRIVER CIRCUIT**

(71) Applicant: **Shanghai Bright Power Semiconductor Co., Ltd.**, Shanghai (CN)

(72) Inventors: **Shungen Sun**, Shanghai (CN); **Liqiang Hu**, Shanghai (CN)

(73) Assignee: **Shanghai Bright Power Semiconductor Co., Ltd.** (CN)

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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H05B 39/00	(2006.01)
H05B 41/14	(2006.01)
H05B 33/08	(2006.01)

(52) **U.S. Cl.**

CPC ***H05B 33/0815*** (2013.01); *Y02B 20/42* (2013.01)

(58) **Field of Classification Search**

CPC H05B 41/34; H05B 33/0803; H05B 39/09; H05B 41/28; H05B 33/0809

USPC .... 315/200 R

See application file for complete search history.

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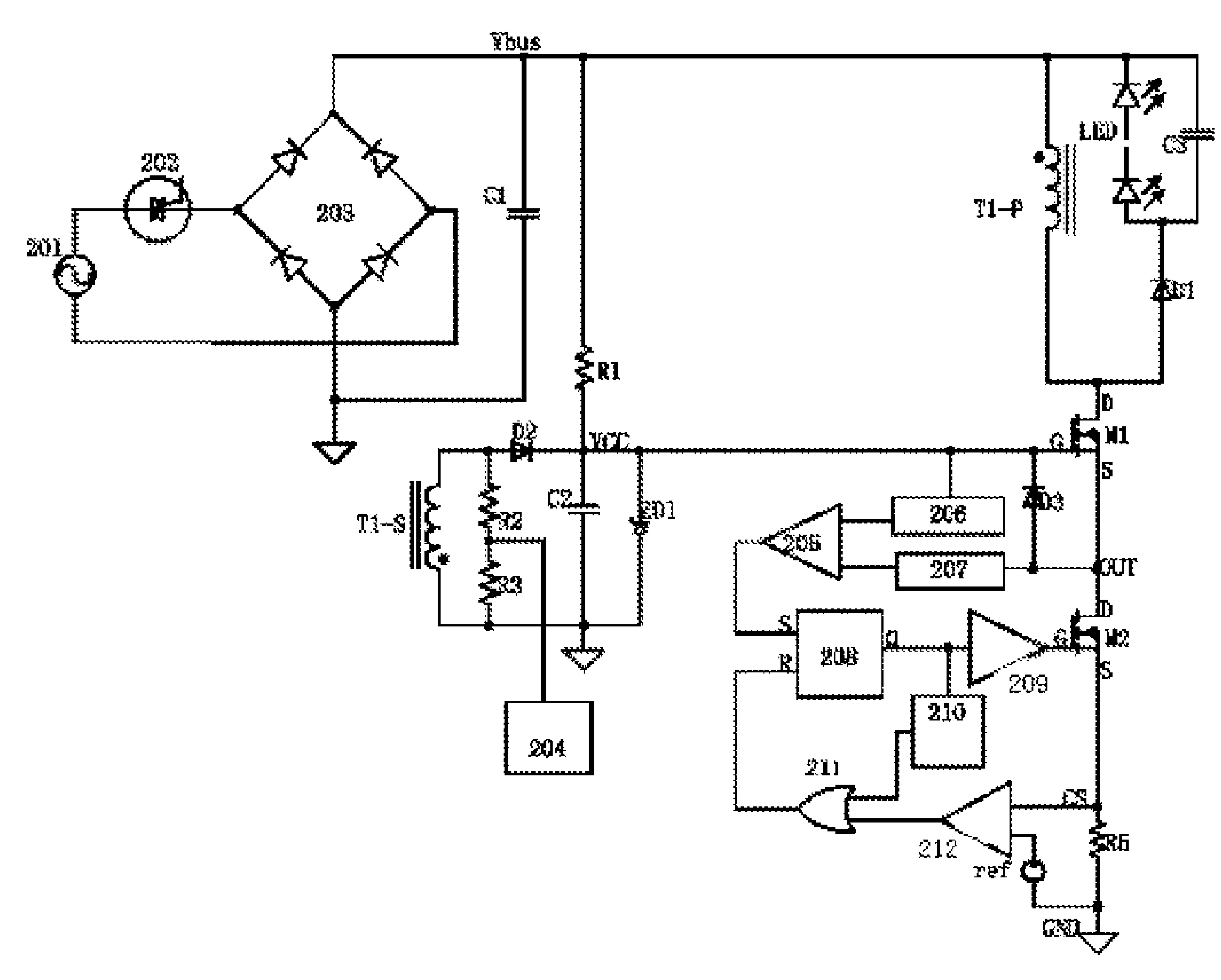
Primary Examiner — Quan Tra

(74) *Attorney, Agent, or Firm* — Lerner, David, Littenberg, Krumholz & Mentlik, LLP

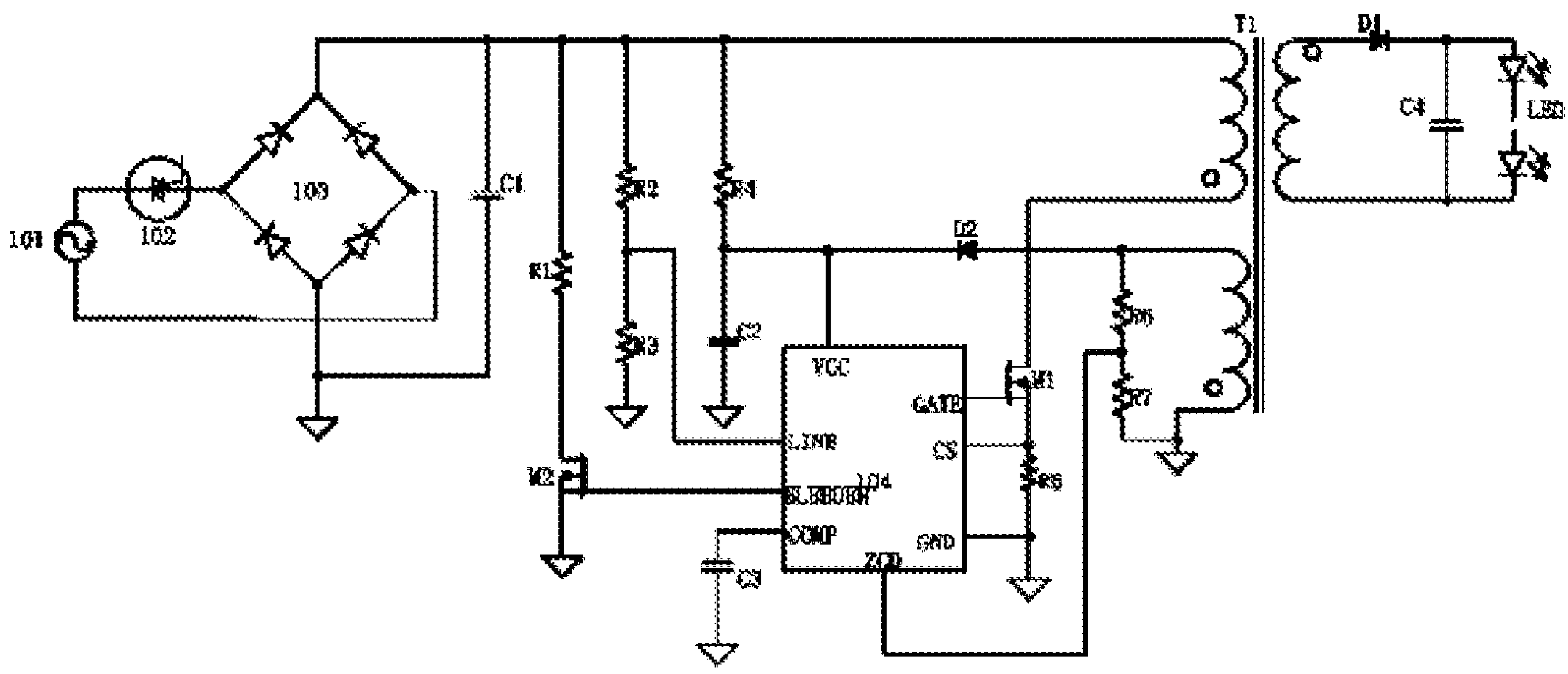
(57) **ABSTRACT**

A TRIAC dimmable light-emitting diode (LED) driver circuit is disclosed, compromising: An alternating-current (AC) voltage connected to a rectifier bridge; An LED load, which is connected to an inductor or a transformer, a power MOS transistor, a low voltage MOS transistor and a current sensing resistor. The LED driver also compromises: a peak current comparator which is used to compare the voltage between a current sensing resistor and a reference voltage; a maximum on-time timer, which is used to detect the on time of the low voltage MOS transistor. When the voltage on the current sensing resistor is higher than the reference voltage or the on time of the low voltage MOS transistor reaches the preset time of the maximum on-time timer, the low voltage MOS transistor is turned off.

8 Claims, 3 Drawing Sheets

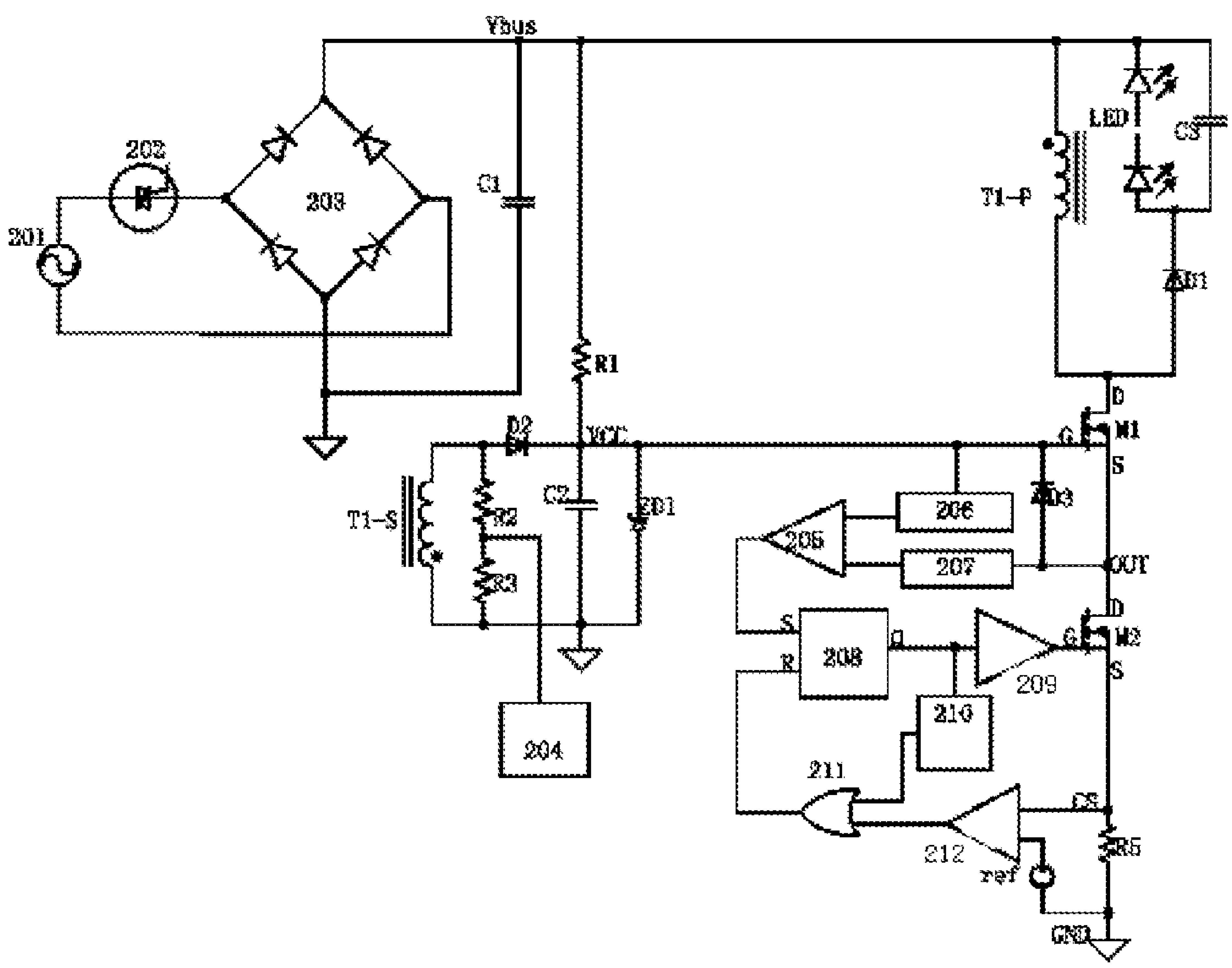


FIRST EMBODIMENT



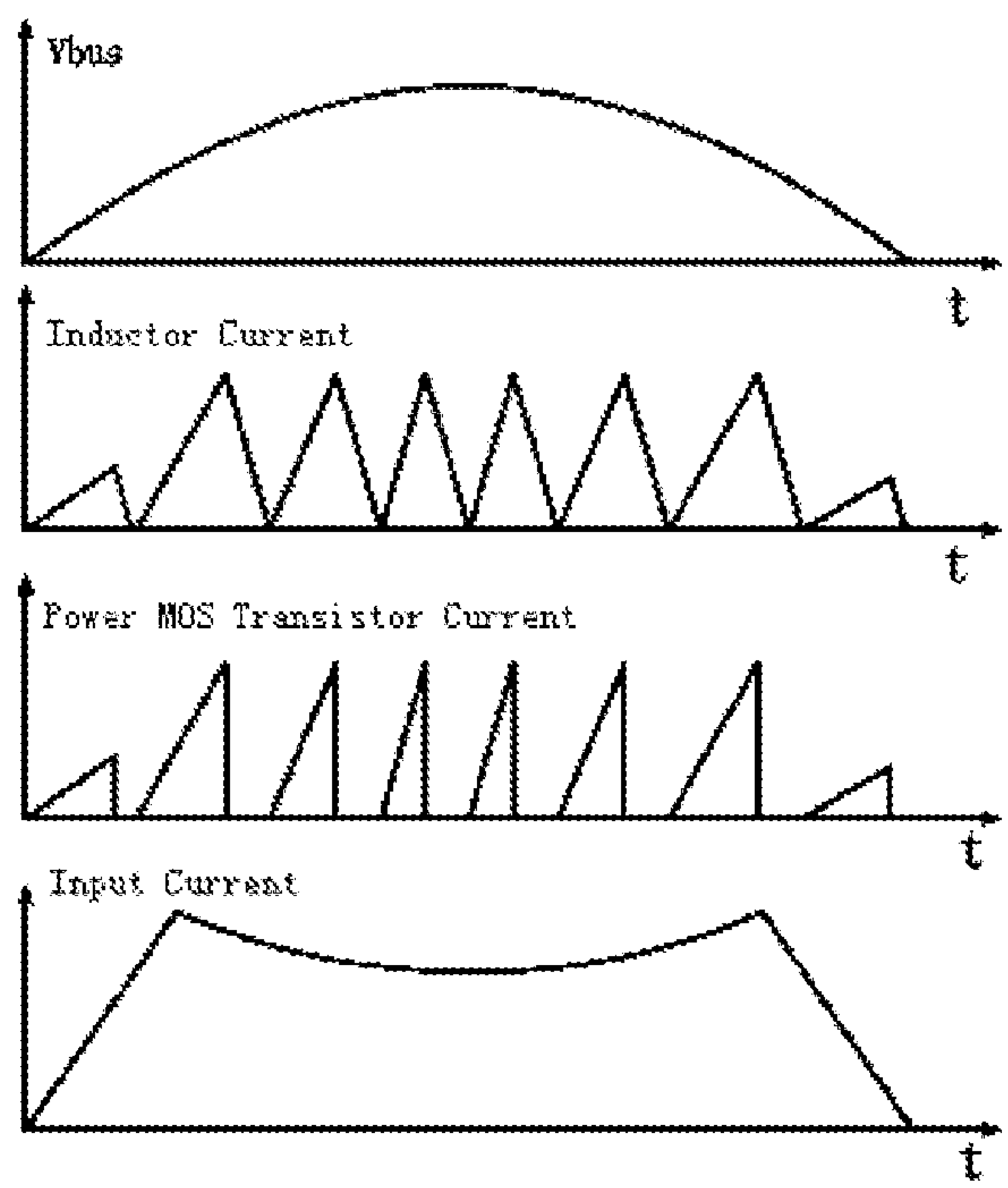
(PRIOR ART)

FIG 1



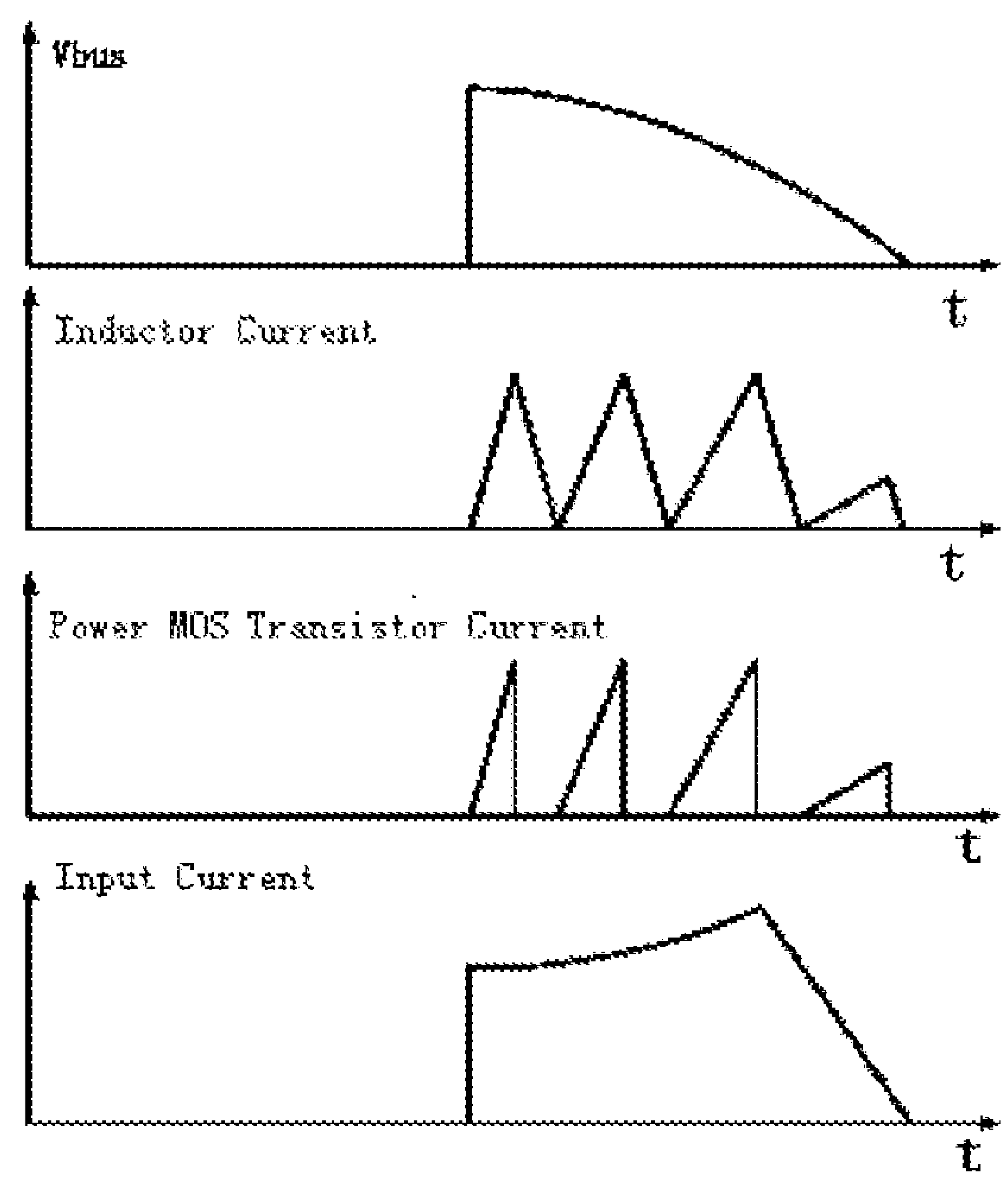
FIRST EMBODIMENT

FIG 2



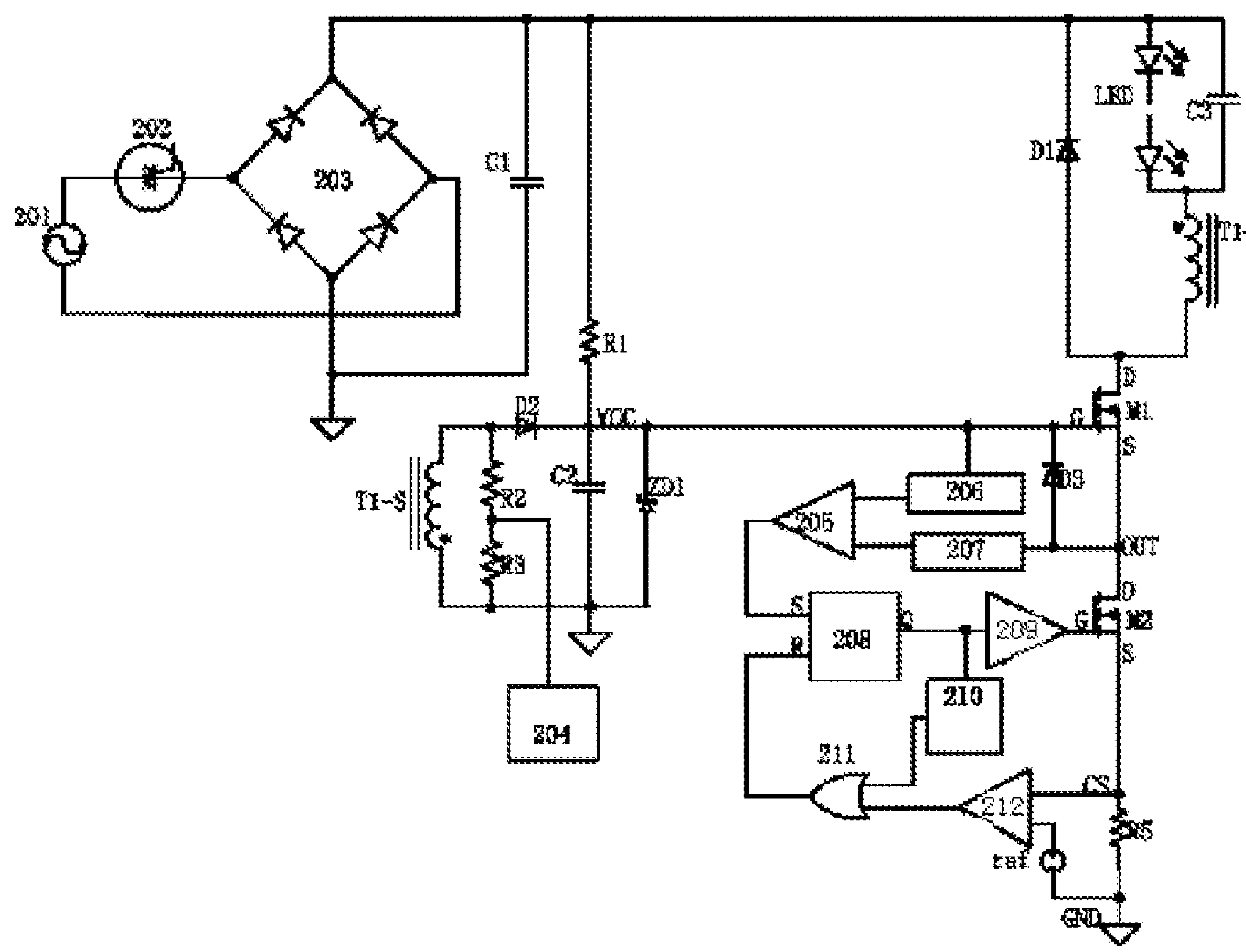
NORMINAL OPERATION WAVEFORM

FIG 3



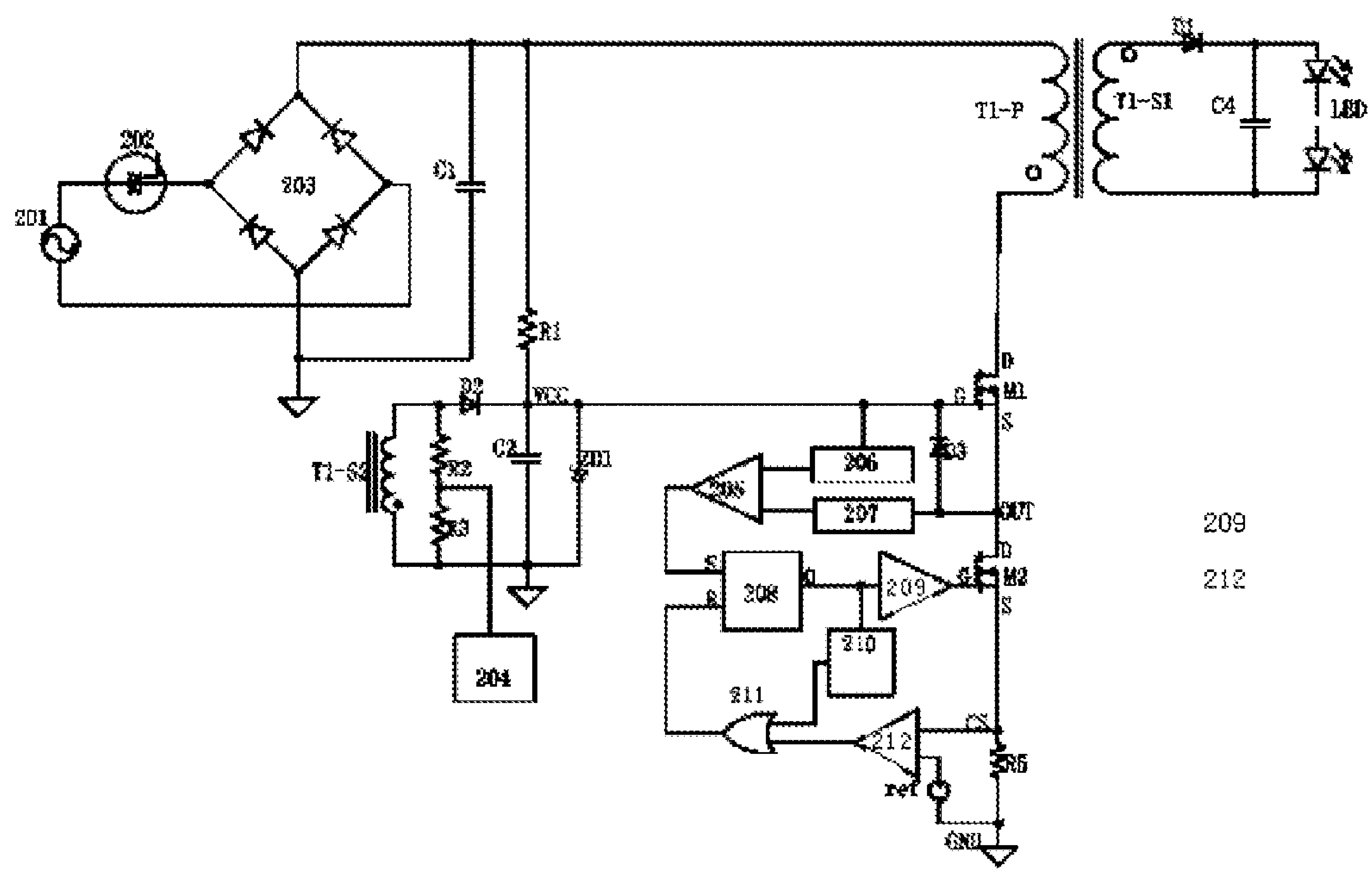
DIMMING OPERATION WAVEFORM

FIG 4



BUCK EMBODIMENT

FIG 5



209

212

FLYBACK EMBODIMENT

FIG 6

TRIAC DIMMABLE LED DRIVER CIRCUIT

CROSS-REFERENCE TO RELATED DOCUMENT

The present application claims priority from CN 201310257527.8 filed on Jun. 26, 2013, the disclosure of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to Light-Emitting Diode ("LED") driver circuits, and in particular, to TRIAC dimmable LED driver circuits.

BACKGROUND OF THE INVENTION

FIG. **1** (Prior Art) is a diagram of a conventional TRIAC dimmable LED driver. As shown in FIG. **1**, an alternating-current (AC) voltage source **101** is in series with a TRIAC dimmer **102**, and is connected to the input terminal of a diode bridge **103**. The diode bridge **103** rectifies the input AC voltage and generates a sinusoidal voltage on capacitor C**1**. Resistor R**4** and capacitor C**2** generates a DC voltage to start up the control IC **104**.

The transformer T**1** has three windings, including a primary winding connected with capacitor C**1** and the drain of the power M**1**, a secondary winding connected with a rectifying diode D**1** and a secondary output capacitor C**4**, and an auxiliary winding connected with a supplying diode D**2** and the circuit ground.

After the circuit starts up, the auxiliary winding powers up the control IC **104**. At the same time, the auxiliary winding provides the rectifier diode D**1** zero-crossing current information and the output over voltage information.

The prior art usually contains a resistor divider R**2** and R**3**, which is used to detect the TRIAC phase cutting angle.

The prior art also contains a bleeding resistor R**1** and a bleeding switch M**2** . When the input current of the flyback converter is small, the control IC **104** turns on the bleeding switch M**2**, providing enough holding current for the TRIAC dimmer.

The prior art has the following disadvantages:

First, the bleeding resistor R**1** and bleeding switch M**2** dissipate too much power, losing the LED driver efficiency and inducing too much heat . The LED driver suffers from high temperature and low reliability.

Second, the control circuit is complex, and the system cost is relatively high.

SUMMARY OF THE INVENTION

The present invention has been developed to solve the problems of the prior art. The present invention provides a TRIAC dimmable LED driver circuit which can eliminate the bleeder circuit and reduce system complexity and cost.

To achieve the above-mentioned object, the present invention discloses a TRIAC dimmable LED driver circuit. An input AC voltage source is connected to a rectifier bridge and an LED load. The LED load is connected to an inductor or a transformer, a power MOS transistor, a low voltage MOS transistor and a current sensing resistor. A peak current comparator is used to compare the voltage between a current sensing resistor and a reference voltage. A maximum on-time timer is used to detect the on time of the low voltage MOS transistor.

When the voltage on the current sensing resistor is higher than the reference voltage or the on time of the low voltage MOS transistor reaches the preset time of the maximum on-time timer, the low voltage MOS transistor is turned off.

Furthermore, one input terminal of the peak current comparator is connected to the current sensing resistor, another input terminal is connected to the reference voltage.

Furthermore, the LED driver circuit includes an OR logic gate and a RS flip-flop. The input signal of the maximum on-time timer is connected to the output of the RS flip-flop. The input signal of the OR logic gate is connected to the output of the maximum on-time timer and the output of the peak current comparator. The output signal of the OR logic gate is connected to the reset terminal of the RS flip-flop.

Furthermore, the LED driver circuit includes a first voltage sensing network, a second voltage sensing network and a demagnetization comparator. The input terminal of the first voltage sensing network is connected to the gate of the power MOS transistor . The input terminal of the second voltage sensing network is connected to the source of the power MOS transistor. The output of the first voltage sensing network and the second voltage sensing network are connected to the input terminals of the demagnetization comparator. The output of the demagnetization comparator is connected to the reset terminal of the RS flip-flop. The first voltage sensing network is composed of resistors and capacitors, and the second voltage sensing network is also composed of resistors and capacitors.

Furthermore, the LED driver includes a switch driver. The input terminal of the switch driver is connected to the output of the RS flip-flop, and the output of the switch driver is connected to the gate of the low voltage MOS transistor.

Furthermore, the inductor or the transformer includes at least two windings. The first winding is connected to the power MOS transistor, and the auxiliary winding is connected to the positive terminal of a supplying diode. The negative terminal of the supplying diode is connected to a supplying capacitor.

Furthermore, the LED driver further includes two resistors and an over voltage protection circuit. The resistors are in series and are connected to the auxiliary winding of the inductor or transformer. The middle point of the resistors is connected to the over voltage protection circuit.

Furthermore, the supplying capacitor is paralleled with a zener diode.

Furthermore, the LED driver is a buck-boost TRIAC dimmable LED driver, or a buck TRIAC dimmable LED driver, or a flyback TRIAC dimmable LED driver.

Compared with the prior art, the TRIAC dimmable LED driver circuit eliminates the bleeder circuit and utilizes the converter input current to provide the holding current for the TRIAC dimmer. Meanwhile, the driver circuit drives the source of the power MOS transistor and greatly reduces the driving current of the power. A simple, efficient and widely compatible TRIAC dimmable LED driver is realized.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantage and spirit of the invention can be understood by the following recitations together with the appended drawings.

FIG. **1** is a circuit diagram of one TRIAC dimmable LED driver circuit in the prior art.

FIG. **2** is a circuit diagram of a buck-boost TRIAC dimmable LED driver circuit illustrated in the present invention.

FIG. **3** is a typical waveform diagram that illustrates the operation of the TRIAC dimmable LED driver circuit illustrated in the present invention.

FIG. **4** is a typical waveform diagram that illustrates the dimming operation of the TRIAC dimmable LED driver circuit illustrated in the present invention.

FIG. **5** is a circuit diagram of a buck TRIAC dimmable LED driver circuit illustrated in the present invention.

FIG. **6** is a circuit diagram of a flyback TRIAC dimmable LED driver circuit illustrated in the present invention.

DETAILED DESCRIPTION

The embodiments according to the invention are hereinafter described with reference to the drawings.

For solving the problem that the power dissipation problem of the bleeder circuit and complexity of the LED driver circuit in the prior art, the present invention discloses a TRIAC dimmable LED driver circuit. The TRIAC dimmable LED driver circuit eliminates the bleeder circuit and utilizes the input current of the converter to provide the holding current for the TRIAC dimmer. Meanwhile, the driver circuit drives the source of the power MOS transistor and greatly reduces the driving current of the power. A simple, efficient and widely compatible TRIAC dimmable LED driver is realized.

The TRIAC dimmable LED driver illustrated in the present invention improves the driving method and control scheme of the prior art. FIG. **2** is a circuit diagram of a TRIAC dimmable LED driver circuit illustrated in the present invention. An input AC voltage source **201** provides power for the LED driver circuit. The AC source **201** is in series with a TRIAC dimmer **202**. The conduction angle of the TRIAC dimmer **202** can be adjusted, thereby the brightness of the LED lamp should vary accordingly.

The output of the TRIAC dimmer **202** is connected to a rectifier bridge **203**. The rectifier bridge **203** converts the sinusoidal input AC voltage to a positive voltage signal Vbus. A bus capacitor C**1** is connected to the output of the rectifier bridge **203** and provides a high frequency current path for the converter.

The first winding T**1**-P of the inductor T**1** is connected between the bus capacitor C**1** and the drain of the power MOS transistor. The positive terminal of a rectifying diode D**1** is connected to the drain of the power MOS transistor, and the negative terminal of the rectifying diode D**1** is connected to an output capacitor C**3** and LED load. The output capacitor C**3** is paralleled with the LED load and connected to Vbus.

The inductor T**1** stores energy when the power MOS transistor M**1** is turned on. And the energy is released to the output capacitor C**3** and LED load through the rectifying diode D**1** when the power MOS transistor M**1** is turned off.

The TRIAC dimmable LED driver utilizes a source driving scheme. A low voltage MOS transistor M**2** is in series with the power MOS transistor M**1**. The drain D of the low voltage MOS transistor M**2** is connected to the source S of the power MOS transistor M**1**. When the low voltage MOS transistor M**2** is turned on, the power MOS transistor M**1** is also turned on. When the low voltage MOS transistor M**2** is turned off, the power MOS transistor M**1** is also turned off.

A supplying resistor R**1** provides the start up current for the LED driver circuit. One terminal of the supplying resistor R**1** is connected to Vbus, another terminal is connected to a supplying capacitor C**1**, and the other terminal of the supplying capacitor C**1** is grounded. The voltage signal on the supplying capacitor C**1** is VCC signal. The gate G of the power MOS transistor M**1** is connected to VCC. The source S of the power MOS transistor M**1** is connected to VCC through a feeding diode D**3**.

The TRIAC dimmable LED driver circuit further includes two voltage sensing networks. The input of the first voltage sensing network **206** is connected to VCC, and the output of the first voltage sensing network **206** is connected to one of the input terminal of a demagnetization comparator **205**. The input of the second voltage sensing network **207** is connected to the source of the power MOS transistor M**1**, and the output of the second voltage sensing network **207** is connected to the other input terminal of the demagnetization comparator **205**. The output of the demagnetization comparator **205** is connected to the reset terminal S of a RS flip-flop **208**. The first voltage sensing network **206** and the second voltage sensing network **207** could be the combination of resistor and resistor, capacitor and capacitor, or resistor and capacitor.

The source of the low voltage MOS transistor M**2** is connected to a current sensing resistor R**5**. The current in the current sensing resistor R**5** is same as the current in the first winding T**1**-P of the inductor T**1**. The voltage on the current sensing resistor R**5** is CS signal. The CS signal is connected to one input terminal of the current comparator **212**, the other input terminal of the current comparator **212** is connected to a reference voltage ref. The output of the current comparator **212** is connected to one of the input terminals of an OR logic gate **211**.

The output Q of the RS flip-flop **208** is connected to the input terminal of a switch driver circuit **209**. The output of the switch driver circuit **209** is connected to the gate of the low voltage MOS transistor M**2**. The output Q of the RS flip-flop **208** is also connected to a maximum on-time timer **210**. The output of the maximum on-time timer is connected to one of the input terminals of the OR logic gate **211**. The output of the OR logic gate **211** is connected to the reset terminal R of the RS flip-flop **208**.

FIG. **3** is a typical waveform diagram that illustrates the operation of the TRIAC dimmable LED driver circuit illustrated in the present invention.

When the low voltage MOS transistor M**2** is turned on, the power MOS transistor M**1** is also turned on. The voltage across the first winding T**1**-P of the inductor T**1** is equal to Vbus. The current in the first winding T**1**-P increases, and the voltage on the current sensing resistor R**5** also increases.

When the voltage on the current sensing resistor R**5** reaches the reference voltage ref, the output of the current comparator **212** is changed high, the output of the OR logic gate **211** is also changed high and the RS flip-flop resets. The switch driver circuit **209** turns off the low voltage MOS transistor M**2** at the same time the power MOS transistor M**1** is also turned off.

Meanwhile, the rectifying diode D**1** starts conducting current. The voltage across the first winding T**1**-P of the inductor T**1** is equal to the output capacitor C**3** voltage, and the current in the first winding T**1**-P decreases. When the current in the rectifying diode D**1** reaches zero, the drain voltage of the power MOS transistor M**1** starts decreasing. Because of the capacitive coupling between drain and source of M**1**, the source voltage of the power MOS transistor M**1** also starts decreasing. At this time, the demagnetization comparator **205** compares the output voltage of the first voltage sensing network **206** and the second voltage sensing network **207**, and the demagnetization comparator **205** is changed high. The RS flip-flop **208** is set, the switch driving circuit **209** turns on the low voltage MOS transistor M**2**, and the power MOS transistor M**1** is also turned on, the next switching cycle is started.

The maximum on-time timer **210** detects the on time of the low voltage MOS transistor M**2**. When the on time of the low voltage MOS transistor M**2** is longer than the system preset value, the maximum on-time timer **210** outputs a signal to the OR logic gate **211**, the RS flip-flop **208** is reset and the switch driver circuit **209** turns off the low voltage MOS transistor M**2**.

As shown in FIG. **3**, the circuit works in quasi-resonant mode, when Vbus voltage is relatively high, the peak inductor current is determined by the reference voltage ref and the current sensing resistor R**5**. When Vbus voltage is relatively low, the maximum on-time time **210** takes action, the peak inductor current is determined by the Vbus voltage and the preset on time. The current of the power MOS transistor M**1** is filtered by the bus capacitor C**1**, and the system input current waveform is sketched in FIG. **3**.

FIG. **4** is a typical waveform diagram that illustrates the dimming operation of the TRIAC dimmable LED driver circuit illustrated in the present invention.

When the lamp is dimmed by the TRIAC dimmer **202**, the conduction angle of the TRIAC dimmer **202** is adjusted. When the TRIAC dimmer **202** blocks the input voltage, Vbus voltage is nearly zero, and the current in inductor T**1** is also zero. When the TRIAC dimmer **202** conducts, Vbus voltage is equal to the input voltage, the LED driver delivers power to the output capacitor C**3** and the LED load. With difference conduction angle of the TRIAC dimmer **202**, the power in the LED load is adjusted, and the dimming function is achieved.

The auxiliary winding T**1**-S of the inductor T**1** is connected to VCC through a supplying diode D**2**. Before the LED driver circuit starts up, the supplying resistor R**1** charges the supplying capacitor C**1** up, and the VCC voltage increases. When the VCC voltage reaches a starting up threshold, the LED driver circuit starts working, and the auxiliary winding T**1**-S powers up the VCC through the supplying diode D**2**.

The present invention further includes an over voltage protection circuit. Dividing resistors R**2** and R**3** is in series and connected to the auxiliary winding T**1**-S, the middle point of the resistors is connected to the input terminal of the over voltage protection circuit **204**. When the rectifying diode D**1** conducts, the auxiliary winding voltage is proportional to the voltage across the LED load. When the LED load is open circuit, the voltage of the output capacitor C**3** increases, and also the auxiliary winding T**1**-S voltage. If the input terminal of the over voltage protection circuit **204** is higher than a preset value, the output over voltage condition is detected, and the low voltage MOS transistor is turned off.

The present invention of the TRIAC dimmable LED driver circuit can be also implemented with the buck topology, as shown in FIG. **5**. The driving method and control scheme of the buck topology implementation is similar with that of the buck-boost implementation and is not repeated here.

The present invention of the TRIAC dimmable LED driver circuit can be also implemented with the flyback topology, as shown in FIG. **6**. The driving method and control scheme of the flyback topology implementation is similar with that of the buck-boost implementation and is not repeated here.

While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention needs not to be limited to the above embodiments. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

What is claimed is:

1. A TRIAC dimmable LED driver circuit comprises an input AC voltage source connected to a rectifier bridge and an LED load, the LED load is connected to an inductor or a transformer, a power MOS transistor, a low voltage MOS transistor and a current sensing resistor, the inductor or transformer includes at least two windings, the first winding is connected to the power MOS transistor, the auxiliary winding is connected to the positive terminal of a supplying diode, the negative terminal of the supplying diode is connected to a supplying capacitor, the LED driver further includes two resistors and an over voltage protection circuit, the resistors are in series and are connected to the auxiliary winding of the inductor or transformer, and the middle point of the resistors are connected to the over voltage protection circuit, the LED driver is characterized in that,

a peak current comparator, which is used to compare the voltage between the current sensing resistor and a reference voltage;

a maximum on-time timer, which is used to detect the on time of the low voltage MOS transistor,

when the voltage on the current sensing resistor is higher than the reference voltage, or the on time of the low voltage MOS transistor reaches the preset time of the maximum on-time timer, the low voltage MOS transistor is turned off.

2. The TRIAC dimmable LED driver circuit of claim **1**, characterized in that one input terminal of the peak current comparator is connected to the current sensing resistor, another input terminal is connected to the reference voltage.

3. The TRIAC dimmable LED driver circuit of claim **1**, characterized in that the LED driver circuit further includes an OR logic gate and a RS flip-flop, the input signal of the maximum on-time timer is the output signal of the RS flip-flop, the input signal of the OR logic gate is the output signal of the maximum on-time timer and the output signal of the peak current comparator, the output signal of the OR logic gate is connected to the reset terminal of the RS flip-flop.

4. The TRIAC dimmable LED driver circuit of claim **3**, characterized in that the LED driver circuit further includes a first voltage sensing network, a second voltage sensing network and a demagnetization comparator, the input terminal of the first voltage sensing network is connected to the gate of the power MOS transistor, the input terminal of the second voltage sensing network is connected to the source of the power MOS transistor, the output of the first voltage sensing network and the second voltage sensing network are connected to the input terminals of the demagnetization comparator, the output of the demagnetization comparator is connected to the reset terminal of the RS flip-flop.

5. The TRIAC dimmable LED driver circuit of claim **4**, characterized in that the first voltage sensing network is composed by resistors and capacitors; and the second voltage sensing network is composed by resistor and capacitors.

6. The TRIAC dimmable LED driver circuit of claim **3**, characterized in that the LED driver further includes a switch driver, the input terminal of the switch driver is connected to the output of the RS flip-flop, the output of the switch driver is connected to the gate of the low voltage MOS transistor.

7. The TRIAC dimmable LED driver circuit of claim **1**, characterized in that the supplying capacitor is paralleled with a zener diode.

8. The TRIAC dimmable LED driver circuit of claim **1**, characterized in that the LED driver is one of a buck-boost TRIAC dimmable LED driver, a buck TRIAC dimmable LED driver, or a flyback TRIAC dimmable LED driver.

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