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Systems and methods for controlling currents flowing through light emitting diodes

Abstract

System and method for controlling one or more light emitting diodes. For example, the system includes: a phase detector configured to process information associated with a rectified voltage generated by a rectifier and related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the phase detector being further configured to generate a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; and a mode detector configured to process information associated with the rectified voltage.

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Background/Summary

1. CROSS-REFERENCES TO RELATED APPLICATIONS (1) This application is a continuation of U.S. patent application Ser. No. 17/554,306, filed Dec. 17, 2021, which is a continuation of U.S. patent application Ser. No. 17/127,711, filed Dec. 18, 2020, which claims priority to Chinese Patent Application No. 201911371960.8, filed Dec. 27, 2019, all of the above applications being incorporated by reference herein for all purposes.

2. BACKGROUND OF THE INVENTION
(1) Certain embodiments of the present invention are directed to circuits. More particularly, some embodiments of the invention provide systems and methods for controlling currents. Merely by way of example, some embodiments of the invention have been applied to light emitting diodes (LEDs). But it would be recognized that the invention has a much broader range of applicability.
(2) With development in the light-emitting diode (LED) lighting market, many LED manufacturers have placed LED lighting products at an important position in market development. The LEDs often provide high brightness, high efficiency, and long lifetime. The LED lighting products usually need dimmer technology to provide consumers with a unique visual experience. Since

Triode for Alternating Current (TRIAC) dimmers have been widely used in other lighting systems such as incandescent lighting systems, the TRIAC dimmers are also increasingly being used in LED lighting systems.

(3) Conventionally, the TRIAC dimmers usually are designed primarily for incandescent lights with pure resistive loads and low luminous efficiency. Such characteristics of incandescent lights often help to meet the requirements of TRIAC dimmers in holding currents. Therefore, the TRIAC dimmers usually are suitable for light dimming when used with incandescent lights. However, when the TRIAC dimmers are used with more efficient LEDs, it is often difficult to meet the requirements of TRIAC dimmers in holding currents due to the reduced input power needed to achieve equivalent illumination to that of incandescent lights. Therefore, conventional LED lighting systems often utilize bleeder units to provide compensation in order to satisfy the requirements of TRIAC dimmers in holding currents.

(4) Additionally, certain TRIAC dimmers have a threshold voltage for current conduction in one direction and another threshold voltage for current conduction in another direction, with these threshold voltages being different in magnitude. The different threshold voltages can cause the TRIAC dimmers to process differently positive and negative values in the AC input signal and thus generate positive and negative waveforms of different sizes. Such difference in waveform size can cause flickering of the LEDs.

(5) FIG. **1** is a simplified diagram showing a conventional TRIAC dimmer. As shown in FIG. **1**, the TRIAC dimmer **100** includes a Triode for Alternating Current (TRIAC) **110**, a Diode for Alternating Current (DIAC) **120**, a variable resistor **130**, and a capacitor **140**. The TRIAC dimmer **100** includes terminals **102** and **104**. The terminal **102** receives an alternating current (AC) input voltage **180** (e.g., VAC), and the terminal **104** is coupled to a LED driver chip **190** through a rectifier **150**.

(6) The TRIAC **110** includes three terminals, one terminal of which is configured to receive the alternating current (AC) input voltage **180** (e.g., VAC) through the terminal **102**, another terminal of which is connected to a terminal of the rectifier **150** through the terminal **104**, and yet another terminal of which is connected to a terminal of the DIAC **120**. The capacitor **140** (e.g., capacitor C.sub.t) includes two terminals, one terminal of which is connected to the terminal of the TRIAC **110** and another terminal of which is connected to one terminal of the variable resistor **130** (e.g., variable resistor R.sub.t). Another terminal of the variable resistor **130** (e.g., variable resistor R.sub.t) is configured to receive the AC input voltage **180** (e.g., VAC) through the terminal **102**. The DIAC **120** includes two terminals, one terminal of which is connected to the terminal of the TRIAC **110** and another terminal of which is connected to both the terminal of the variable resistor **130** (e.g., variable resistor R.sub.t) and the terminal of the capacitor **140** (e.g., capacitor C.sub.t).

(7) When the AC input voltage **180** (e.g., VAC) is in the positive half cycle during which the AC input voltage **180** (e.g., VAC) is larger than zero, the voltage at the node T.sub.1 is higher than the voltage at the node T.sub.2 so that the RC charging circuit that includes the variable resistor **130** (e.g., variable resistor R.sub.t) and the capacitor **140** (e.g., capacitor C.sub.t) charges the capacitor **140** (e.g., capacitor C.sub.t). The voltage drop between two terminals of the capacitor **140** (e.g., capacitor C.sub.t) is equal to the voltage at the node G minus the voltage at the node T.sub.2. If the voltage drop between two terminals of the capacitor **140** (e.g., capacitor C.sub.t) becomes larger than a predetermined positive-direction voltage that is equal to a positive-direction threshold voltage (e.g., V.sub.BD), the DIAC **120** becomes turned on and the TRIAC **110** is also turned on, so the voltage at the node T.sub.1 and the voltage at the node T.sub.2 become equal, causing the capacitor **140** (e.g., capacitor C.sub.t) to discharge through the variable resistor **130** (e.g., variable resistor R.sub.t). The positive-direction threshold voltage (e.g., V.sub.BD) is larger than zero volts (e.g., being equal to about 30 volts).

(8) When the AC input voltage **180** (e.g., VAC) is in the negative half cycle during which the AC input voltage **180** (e.g., VAC) is smaller than zero, the voltage at the node T.sub.1 is lower than the

voltage at the node T.sub.2 so that the RC charging circuit that includes the variable resistor **130** (e.g., variable resistor R.sub.t) and the capacitor **140** (e.g., capacitor C.sub.t) charges the capacitor **140** (e.g., capacitor C.sub.t). The voltage drop between two terminals of the capacitor **140** (e.g., capacitor C.sub.t) is equal to the voltage at the node G minus the voltage at the node T.sub.2. If the voltage drop between two terminals of the capacitor **140** (e.g., capacitor C.sub.t) becomes less than a predetermined negative-direction voltage that is equal to a negative-direction threshold voltage (e.g., V.sub.RD) multipIled by −1, the DIAC **120** becomes turned on and the TRIAC **110** is also turned on, so the voltage at the node T.sub.1 and the voltage at the node T.sub.2 become equal, causing the capacitor **140** (e.g., capacitor C.sub.t) to discharge through the variable resistor **130** (e.g., variable resistor R.sub.t). The negative-direction threshold voltage (e.g., V.sub.RD) is larger than zero.

(9) If the current that flows though the TRIAC **110** is larger than a holding current of the TRIAC **110**, the TRIAC **110** remains turned on, and if the current that flows though the TRIAC **110** is smaller than the holding current of the TRIAC **110**, the TRIAC **110** becomes turned off. Additionally, the variable resistor **130** (e.g., variable resistor R.sub.t) is adjusted to change the time duration that is needed to charge or discharge the capacitor **140** (e.g., capacitor C.sub.t), thus also changing the phase range within which the waveform of the AC input voltage **180** (e.g., VAC) is clipped by the TRIAC dimmer **100**.

(10) FIG. **2** is a simplified conventional diagram showing a current flowing through the TRIAC **110** as a function of the voltage drop between two terminals of the capacitor **140** as shown in FIG. **1**. The current I.sub.T represents the current that flows through the TRIAC **110**, and the voltage V.sub.GT2 represents the voltage drop between two terminals of the capacitor **140**, which is equal to the voltage at the node G minus the voltage at the node T.sub.2. If the current I.sub.T is larger than zero, the current flows through the TRIAC **110** from the node T.sub.1 to the node T.sub.2, and if the current I.sub.T is smaller than zero, the current flows through the TRIAC **110** from the node T.sub.2 to the node T.sub.1. Also, if the voltage V.sub.GT2 is larger than zero, the voltage at the node G is larger than the voltage at the node T.sub.2, and if the voltage V.sub.GT2 is smaller than zero, the voltage at the node G is smaller than the voltage at the node T.sub.2. Additionally, V.sub.BD represents the positive-direction threshold voltage, and V.sub.RD represents the negative-direction threshold voltage.

(11) As shown in FIG. **2**, after the TRIAC **110** is turned on, if the current I.sub.T that flows though the TRIAC **110** is larger than the holding current (e.g., I.sub.H) of the TRIAC **110**, the TRIAC **110** remains turned on, and if the current that flows though the TRIAC **110** is smaller than the holding current of the TRIAC **110**, the TRIAC **110** becomes turned off. Also as shown in FIG. **2**, after the TRIAC **110** becomes turned off, if the current I.sub.T that flows though the TRIAC **110** is larger than the latching current (e.g., I.sub.L) of the TRIAC **110**, the TRIAC **110** becomes turned on, and if the current that flows though the TRIAC **110** is smaller than the latching current (e.g., I.sub.L) of the TRIAC **110**, the TRIAC **110** remains turned off. The latching current (e.g., I.sub.L) of the TRIAC **110** is larger than the holding current (e.g., I.sub.H) of the TRIAC **110**.

(12) As an example, the positive-direction threshold voltage V.sub.BD is not equal to the negative-direction threshold voltage V.sub.RD, so given the same resistance value for the variable resistor R.sub.t, the phase range within which the waveform of the AC input voltage VAC is clipped by the TRIAC dimmer **100** during the positive half cycle of the AC input voltage VAC is not equal to the phase range within which the waveform of the AC input voltage VAC is clipped by the TRIAC dimmer **100** during the negative half cycle of the AC input voltage VAC. For example, if the positive-direction threshold voltage V.sub.BD is significantly different from the negative-direction threshold voltage V.sub.RD, the TRIAC dimmer **100** generates a waveform during the positive half cycle of the AC input voltage VAC and a waveform during the negative half cycle of the AC input voltage VAC, wherein the sizes of these two waveforms are significantly different, causing flickering of the one or more LEDs **190**.

(13) Hence it is highly desirable to improve the techniques related to LED lighting systems.

3. BRIEF SUMMARY OF THE INVENTION

(14) Certain embodiments of the present invention are directed to circuits. More particularly, some embodiments of the invention provide systems and methods for controlling currents. Merely by way of example, some embodiments of the invention have been appIled to light emitting diodes (LEDs). But it would be recognized that the invention has a much broader range of applicability.

(15) According to some embodiments, a system for controlling one or more light emitting diodes includes: a phase detector configured to process information associated with a rectified voltage generated by a rectifier and related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the phase detector being further configured to generate a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; a mode detector configured to process information associated with the rectified voltage, determine whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage, and generate a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; a modified signal generator configured to receive the phase detection signal from the phase detector and the mode detection signal from the mode detector, modify the phase detection signal based at least in part on the mode detection signal, and generate a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; and a current controller configured to receive the modified signal, the current controller being further configured to control, based at least in part of the modified signal, a first current flowing through one or more light emitting diodes configured to receive the rectified voltage; wherein: the first time duration and the second time duration are different in magnitude; and the third time duration and the fourth time duration are the same in magnitude.

(16) According to certain embodiments, a system for controlling one or more light emitting diodes includes: a phase detector configured to process information associated with a rectified voltage generated by a rectifier and related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the signal detector being further configured to generate a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; a mode detector configured to process information associated with the rectified voltage, determine whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage, and generate a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; and a modified signal generator configured to receive the phase detection signal from the phase detector and the mode detection signal from the mode detector, the modified signal generator being further configured to generate, based at least in part on the phase detection signal and the mode detection signal, a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; wherein: the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; the fourth time duration is smaller than the second duration in magnitude; and the third time duration and the fourth time duration are equal in magnitude.

(17) According to some embodiments, a method for controlling one or more light emitting diodes includes: processing information associated with a rectified voltage related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage; generating a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; determining whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage; generating a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; receiving the phase detection signal and the mode detection signal; modifying the phase detection signal based at least in part on the mode detection signal; generating a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; receiving the modified signal; and controlling, based at least in part of the modified signal, a first current flowing through one or more light emitting diodes configured to receive the rectified voltage; wherein: the first time duration and the second time duration are different in magnitude; and the third time duration and the fourth time duration are the same in magnitude.
(18) According to certain embodiments, a method for controlling one or more light emitting diodes includes: processing information associated with a rectified voltage related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage; generating a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; determining whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage; generating a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; receiving the phase detection signal and the mode detection signal; and generating, based at least in part on the phase detection signal and the mode detection signal, a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; wherein: the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; the fourth time duration is smaller than the second duration in magnitude; and the third time duration and the fourth time duration are equal in magnitude.
(19) Depending upon embodiment, one or more benefits may be achieved. These benefits and various additional objects, features and advantages of the present invention can be fully appreciated with reference to the detailed description and accompanying drawings that follow.

Description

4. BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a simplified diagram showing a conventional TRIAC dimmer.
(2) FIG. **2** is a simplified conventional diagram showing a current flowing through the TRIAC as a function of the voltage drop between two terminals of the capacitor as shown in FIG. **1**.
(3) FIG. **3** shows simplified timing diagrams related to the TRIAC dimmer as shown in FIG. **1** according to some embodiments.

(4) FIG. **4** is a simplified diagram showing an LED lighting system according to certain embodiments of the present invention.
(5) FIG. **5** is a simplified diagram showing certain components of the waveform adjustment unit as part of the LED lighting system as shown in FIG. **4** according to some embodiments of the present invention.
(6) FIG. **6** is a simplified diagram showing certain components of the control unit for LED output current as part of the LED lighting system as shown in FIG. **4** according to certain embodiments of the present invention.
(7) FIG. **7** is a simplified diagram showing certain components of the control unit for LED output current as part of the LED lighting system as shown in FIG. **4** according to some embodiments of the present invention.
(8) FIG. **8** shows simplified timing diagrams for the LED lighting system if the TRIAC dimmer is a leading-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **6** according to some embodiments of the present invention.
(9) FIG. **9** shows simplified timing diagrams for the LED lighting system if the TRIAC dimmer is a trailing-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **6** according to certain embodiments of the present invention.
(10) FIG. **10** shows simplified timing diagrams for the LED lighting system if the TRIAC dimmer is a leading-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **7** according to some embodiments of the present invention.
(11) FIG. **11** shows simplified timing diagrams for the LED lighting system if the TRIAC dimmer is a trailing-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **7** according to certain embodiments of the present invention.
(12) FIG. **12** is a simplified diagram showing a method for the LED lighting system as shown in FIG. **4** and FIG. **5** according to some embodiments of the present invention.
(13) FIG. **13** is a simplified diagram showing a method for the LED lighting system as shown in FIG. **4** and FIG. **5** according to certain embodiments of the present invention.
5. DETAILED DESCRIPTION OF THE INVENTION
(14) Certain embodiments of the present invention are directed to circuits. More particularly, some embodiments of the invention provide systems and methods for controlling currents. Merely by way of example, some embodiments of the invention have been appIled to light emitting diodes (LEDs). But it would be recognized that the invention has a much broader range of applicability.
(15) FIG. **3** shows simplified timing diagrams related to the TRIAC dimmer **100** as shown in FIG. **1** according to some embodiments. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **3**, the waveform **310** represents the rectified voltage (e.g., VIN) as a function of time, the waveform **320** represents the logic signal (e.g., Dim_on) that represents size of waveform for the rectified voltage as a function of time, and the waveform **330** represents the output current (e.g., I.sub.led) flowing through the one or more LEDs as a function of time. For example, the logic signal (e.g., Dim_on) is an internal signal generated by the LED driver chip **190**.
(16) As shown by the waveforms **310** and **320**, if the rectified voltage VIN is larger than a threshold voltage V.sub.x, the logic signal Dim_on is at a logic high level, and if the rectified voltage VIN is smaller than the threshold voltage V.sub.x, the logic signal Dim_on is at a logic low level according to certain embodiments. As an example, the threshold voltage V.sub.x is equal to a predetermined voltage value that is selected from a range from 10 volts to 30 volts. For example, during a positive half cycle of the AC input voltage VAC, the logic signal Dim_on remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.1. As an example, during a negative half cycle of the AC input voltage VAC, the logic signal Dim_on remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.2. As shown in FIG. **3**, the phase

range ϕ.sub.1 and the phase range ϕ.sub.2 are not equal, indicating the size of the waveform during the positive half cycle of the AC input voltage VAC and the size of the waveform during the negative half cycle of the AC input voltage VAC are different according to some embodiments.
(17) As shown by the waveforms **310** and **330**, if the rectified voltage VIN is larger than a threshold voltage V.sub.o, the output current (e.g., I.sub.led) is at a high current level **332**, and if the rectified voltage VIN is smaller than the threshold voltage V.sub.o, the output current (e.g., I.sub.led) is at a low current level **334** (e.g., zero) according to some embodiments. As an example, the threshold voltage V.sub.o is higher than the threshold voltage V.sub.x. For example, in the positive half cycle of the AC input voltage VAC, the time duration during which the output current (e.g., I.sub.led) is at the current level **332** can be determined by the time duration during which the logic signal Dim_on is at the logic high level, so the time duration during which the logic signal Dim_on is at the logic high level is used to represent the time duration during which the output current (e.g., I.sub.led) is at the current level **332**. As an example, in the negative half cycle of the AC input voltage VAC, the time duration during which the output current (e.g., I.sub.led) is at the current level **332** can be determined by the time duration during which the logic signal Dim_on is at the logic high level, so the time duration during which the logic signal Dim_on is at the logic high level is used to represent the time duration during which the output current (e.g., I.sub.led) is at the current level **332**.
(18) In some examples, the phase range ϕ.sub.1 and the phase range ϕ.sub.2 are not equal, so the time duration during which the output current (e.g., I.sub.led) is at the current level **332** in the positive half cycle of the AC input voltage VAC and the time duration during which the output current (e.g., I.sub.led) is at the current level **332** in the negative half cycle of the AC input voltage VAC are also different, causing the average of the output current (e.g., I.sub.led) in the positive half cycle of the AC input voltage VAC and the average of the output current (e.g., I.sub.led) in the negative half cycle of the AC input voltage VAC to be different. In certain examples, if the average of the output current (e.g., I.sub.led) in the positive half cycle of the AC input voltage VAC and the average of the output current (e.g., I.sub.led) in the negative half cycle of the AC input voltage VAC are significantly different, human eyes can perceive flickering of the one or more LEDs.
(19) FIG. **4** is a simplified diagram showing an LED lighting system according to certain embodiments of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **4**, the LED lighting system **400** includes a TRIAC dimmer **470**, a rectifier **480** (e.g., BD1), one or more LEDs **490**, a bleeder current control and generation unit **450**, a voltage detection unit **460**, a phase detection unit **410**, a mode detection unit **420**, a waveform adjustment unit **430**, and a control unit **440** for LED output current according to certain embodiments. For example, the rectifier **480** (e.g., BD1) includes a bridge rectifier circuit. As an example, the bleeder current control and generation unit **450**, the phase detection unit **410**, the mode detection unit **420**, the waveform adjustment unit **430**, and the control unit **440** for LED output current are on the same chip, but the voltage detection unit **460** is not on the same chip. For example, the bleeder current control and generation unit **450**, the phase detection unit **410**, the mode detection unit **420**, the waveform adjustment unit **430**, the control unit **440** for LED output current, and the voltage detection unit **460** are on the same chip. Although the above has been shown using a selected group of components for the LED lighting system, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. Further details of these components are found throughout the present specification.
(20) In some embodiments, after the system **400** is powered on, an alternating current (AC) input voltage **472** (e.g., VAC) is received by the TRIAC dimmer **470** and rectified by the rectifier **480** (e.g., BD1) to generate a rectified voltage **483** (e.g., VIN). For example, the rectified voltage **483**

(e.g., VIN) is used to control an output current **491** that flows through the one or more LEDs **490**. In certain embodiments, the rectified voltage **483** (e.g., VIN) is received by the voltage detection unit **460**, which in response outputs a sensing signal **461** (e.g., LS) to the phase detection unit **410** and the mode detection unit **420**. For example, the voltage detection unit **460** includes a resistor **462** (e.g., R1) and a resistor **464** (e.g., R2), and the resistors **462** and **464** form a voltage divider. As an example, the resistor **462** (e.g., R1) and the resistor **464** (e.g., R2) are in series and are biased between the rectified voltage **483** (e.g., VIN) and a ground voltage.

(21) According to certain embodiments, the mode detection unit **420** receives the sensing signal **461** (e.g., LS), determines whether the TRIAC dimmer **470** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based at least in part on the sensing signal **461** (e.g., LS), generates a mode signal **421** that indicates whether the TRIAC dimmer **470** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer, and output the mode signal **421** to the bleeder current control and generation unit **450** and the waveform adjustment unit **430**. For example, the mode detection unit **420** generates the mode signal **421** based at least in part on the sensing signal **461** (e.g., LS). According to some embodiments, the bleeder current control and generation unit **450** receives the mode signal **421** and generates a bleeder current **451** based at least in part on the mode signal **421**. As an example, the bleeder current **451** is used to ensure that the current flowing through the TRIAC dimmer **470** does not fall below a holding current of the TRIAC dimmer **470** in order to maintain normal operation of the TRIAC dimmer **470**.

(22) In some embodiments, the phase detection unit **410** receives the sensing signal **461** (e.g., LS), generates a logic signal **411** (e.g., Dim_on) based at least in part on the sensing signal **461** (e.g., LS), and outputs the logic signal **411** (e.g., Dim_on) to the waveform adjustment unit **430**. For example, if the sensing signal **461** (e.g., LS) is larger than a threshold signal, the logic signal **411** (e.g., Dim_on) is at a logic high level. As an example, if the sensing signal **461** (e.g., LS) is smaller than the threshold signal, the logic signal **411** (e.g., Dim_on) is at a logic low level.

(23) In certain embodiments, the waveform adjustment unit **430** receives the logic signal **411** (e.g., Dim_on) and the mode signal **421**, generates a logic signal **432** (e.g., Dim_on′) by modifying the logic signal **411** (e.g., Dim_on) based at least in part on the mode signal **421**, and outputs the logic signal **432** (e.g., Dim_on′) to the control unit **440** for LED output current. For example, the logic signal **411** (e.g., Dim_on) is modified based at least in part on the mode signal **421** in order to eliminate the effect of different sizes of the waveforms of the rectified voltage **483** (e.g., VIN) during the positive half cycle of the AC input voltage **472** (e.g., VAC) and during the negative half cycle of the AC input voltage **472** (e.g., VAC).

(24) According to certain embodiments, the control unit **440** for LED output current receives the logic signal **432** (e.g., Dim_on′) and uses the logic signal **432** (e.g., Dim_on′) to control the output current **491** that flows through the one or more LEDs **490**. For example, the control unit **440** for LED output current includes three terminals, one terminal of which is configured to receive the logic signal **432** (e.g., Dim_on′), another terminal of which is biased to the ground voltage, and yet another terminal of which is connected to one terminal of the one or more LEDs **490**. As an example, the one or more LEDs **490** includes another terminal configured to receive the rectified voltage **483** (e.g., VIN).

(25) FIG. **5** is a simplified diagram showing certain components of the waveform adjustment unit **430** as part of the LED lighting system **400** as shown in FIG. **4** according to some embodiments of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **5**, the waveform adjustment unit **430** includes an edge detection unit **510**, a signal processing unit **520**, and a signal outputting unit **530** according to certain embodiments. For example, the signal processing unit **520** includes a delay sub-unit **522** and a control sub-unit **524**. Although the above has been shown using a selected group of components for the waveform adjustment unit, there can be many alternatives, modifications, and variations. For

example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. Further details of these components are found throughout the present specification.

(26) In certain embodiments, the edge detection unit **510** receives the logic signal **411** (e.g., Dim_on), detects a rising edge or a falling edge of the logic signal **411** (e.g., Dim_on), generate a detection signal **511** indicating the occurrence of the rising edge or the falling edge of the logic signal **411** (e.g., Dim_on), and output the detection signal **511** to the signal processing unit **520**. For example, if the edge detection unit **510** detects a rising edge of the logic signal **411** (e.g., Dim_on), the edge detection unit **510** generates the detection signal **511** to indicate the occurrence of the rising edge of the logic signal **411** (e.g., Dim_on). As an example, if the edge detection unit **510** detects a falling edge of the logic signal **411** (e.g., Dim_on), the edge detection unit **510** generates the detection signal **511** to indicate the occurrence of the falling edge of the logic signal **411** (e.g., Dim_on). In some examples, the detection signal **511** indicates whether a change of the logic signal **411** (e.g., Dim_on) has occurred and also indicates whether the change of the logic signal **411** (e.g., Dim_on) corresponds to a rising edge of the logic signal **411** (e.g., Dim_on) or a falling edge of the logic signal **411** (e.g., Dim_on).

(27) In some embodiments, the signal processing unit **520** receives the detection signal **511**, the mode signal **421**, and the logic signal **411** (e.g., Dim_on), generates a control signal **521** based at least in part on the detection signal **511**, the mode signal **421**, and the logic signal **411** (e.g., Dim_on), and outputs the control signal **521** to the signal outputting unit **530**. For example, the signal processing unit **520** includes the delay sub-unit **522** and the control sub-unit **524**.

(28) According to certain embodiments, the delay sub-unit **522** receives the detection signal **511** and the mode signal **421**, generates a delayed signal **523** (e.g., Dim_on_T) based at least in part on the detection signal **511** and the mode signal **421**, and outputs the delayed signal **523** to the control sub-unit **524**. In some examples, if the mode signal **421** indicates that the TRIAC dimmer **470** is a leading-edge TRIAC dimmer, the delay sub-unit **522** generates the delayed signal **523** (e.g., Dim_on_T) by delaying, by a predetermined delay of time, the rising edge of the logic signal **411** (e.g., Dim_on) as indicated by the detection signal **511**. In certain examples, if the mode signal **421** indicates that the TRIAC dimmer **470** is a trailing-edge TRIAC dimmer, the delay sub-unit **522** generates the delayed signal **523** (e.g., Dim_on_T) by delaying, by the predetermined delay of time, the falling edge of the logic signal **411** (e.g., Dim_on) as indicated by the detection signal **511**. For example, the predetermined delay of time is equal to a half cycle of the AC input voltage **472** (e.g., VAC) in time duration.

(29) According to some embodiments, the control sub-unit **524** receives the delayed signal **523** and the logic signal **411** (e.g., Dim_on), generates the control signal **521** based at least in part on the delayed signal **523** and the logic signal **411** (e.g., Dim_on), and outputs the control signal **521** to the signal outputting unit **530**. In certain examples, the control signal **521** is the same as the delayed signal **523**, except that during the first half cycle of the AC input voltage **472** (e.g., VAC), the control signal **521** is the same as the logic signal **411** (e.g., Dim_on). For example, the first half cycle of the AC input voltage **472** (e.g., VAC) is either a positive half cycle or a negative half cycle of the AC input voltage **472** (e.g., VAC). As an example, the first half cycle of the AC input voltage **472** (e.g., VAC) occurs immediately after the system **400** is powered on.

(30) In certain embodiments, the signal outputting unit **530** receives the control signal **521** and the logic signal **411** (e.g., Dim_on), generates the logic signal **432** (e.g., Dim_on′) based at least in part on the control signal **521** and the logic signal **411** (e.g., Dim_on), and outputs the logic signal **432** (e.g., Dim_on′) to the control unit **440** for LED output current. For example, the signal outputting unit **530** includes an AND gate **532**. As an example, the AND gate **532** receives the control signal **521** and the logic signal **411** (e.g., Dim_on) and generates the logic signal **432** (e.g., Dim_on′).

(31) As discussed above and further emphasized here, FIG. **5** is merely an example, which should

not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. In some examples, the edge detection unit **510** is removed from the waveform adjustment unit **430**, and the signal processing unit **520** receives the logic signal **411** (e.g., Dim_on) instead of the detection signal **511** and generates the control signal **521** based at least in part on the logic signal **411** (e.g., Dim_on) and the mode signal **421**. For example, the logic signal **411** (e.g., Dim_on) indicates whether a change of the logic signal **411** (e.g., Dim_on) has occurred and also indicates whether the change of the logic signal **411** (e.g., Dim_on) corresponds to a rising edge of the logic signal **411** (e.g., Dim_on) or a falling edge of the logic signal **411** (e.g., Dim_on). As an example, the delay sub-unit **522** receives the logic signal **411** (e.g., Dim_on) instead of the detection signal **511** and generates the delayed signal **523** (e.g., Dim_on_T) based at least in part on the logic signal **411** (e.g., Dim_on) and the mode signal **421**.

(32) FIG. **6** is a simplified diagram showing certain components of the control unit **440** for LED output current as part of the LED lighting system **400** as shown in FIG. **4** according to certain embodiments of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **6**, the control unit **440** for LED output current includes a control signal generator **610**, a transistor **620**, a switch **630** and a resistor **640**. Although the above has been shown using a selected group of components for the control unit, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. Further details of these components are found throughout the present specification.

(33) In some embodiments, the control signal generator **610** receives the logic signal **432** (e.g., Dim_on′), generates a control signal **612** based at least in part on the logic signal **432** (e.g., Dim_on′), and outputs the control signal **612** to a gate terminal of the transistor **620**. In certain examples, the transistor **620** includes the gate terminal, a drain terminal, and a source terminal. For example, the drain terminal of the transistor **620** is connected to one terminal of the one or more LEDs **490**. As an example, the source terminal of the transistor **620** is connected to a terminal of the resistor **640**, which also includes another terminal biased to the ground voltage. In certain embodiments, the gate terminal of the transistor **620** is also connected to a terminal of the switch **630**, which also includes another terminal biased to the ground voltage. In some examples, the switch **630** receives the logic signal **432** (e.g., Dim_on′). For example, if the logic signal **432** (e.g., Dim_on′) is at the logic high level, the switch **630** is open. As an example, if the logic signal **432** (e.g., Dim_on′) is at the logic low level, the switch **630** is closed.

(34) According to some embodiments, if the logic signal **432** (e.g., Dim_on′) is at the logic low level, the switch **630** is closed, so that the gate terminal of the transistor **620** is biased to the ground voltage. For example, if the gate terminal of the transistor **620** is biased to the ground voltage, the transistor **620** is turned off so that the output current **491** that flows through the one or more LEDs **490** is not allowed to be generated (e.g., the output current **491** being equal to zero).

(35) According to certain embodiments, if the logic signal **432** (e.g., Dim_on′) is at the logic high level, the switch **630** is open, so that the voltage of the gate terminal of the transistor **620** is controlled by the control signal **612**. For example, the control signal **612** is generated by the control signal generator **610** based at least in part on the logic signal **432** (e.g., Dim_on′). As an example, the control signal **612** is generated at a constant voltage level, and the constant voltage level of the control signal **612** is used by the transistor **620** to generate the output current **491** at a constant current level for a time duration during which the rectified voltage **483** (e.g., VIN) exceeds a threshold voltage that is needed to provide the forward bias voltage for the one or more LEDs **490**.

(36) FIG. **7** is a simplified diagram showing certain components of the control unit **440** for LED output current as part of the LED lighting system **400** as shown in FIG. **4** according to some

embodiments of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **7**, the control unit **440** for LED output current includes a control signal generator **710**, a transistor **720**, a switch **730**, a resistor **740**, and an operation signal generator **750**. Although the above has been shown using a selected group of components for the control unit, there can be many alternatives, modifications, and variations. For example, some of the components may be expanded and/or combined. Other components may be inserted to those noted above. Depending upon the embodiment, the arrangement of components may be interchanged with others replaced. Further details of these components are found throughout the present specification.

(37) In some embodiments, the control signal generator **710** receives the logic signal **432** (e.g., Dim_on′), generates a control signal **712** (e.g., a drive signal) based at least in part on the logic signal **432** (e.g., Dim_on′), and outputs the control signal **712** to a gate terminal of the transistor **720**. In certain examples, the transistor **720** includes the gate terminal, a drain terminal, and a source terminal. For example, the drain terminal of the transistor **720** is connected to one terminal of the one or more LEDs **490**. As an example, the source terminal of the transistor **620** is connected to a terminal of the resistor **740**, which also includes another terminal biased to the ground voltage. In certain embodiments, the gate terminal of the transistor **720** is also connected to a terminal of the switch **730**, which also includes another terminal biased to the ground voltage. In some examples, the switch **730** receives an operation signal **752**. For example, if the operation signal **752** is at the logic high level, the switch **730** is open. As an example, if the operation signal **752** is at the logic low level, the switch **730** is closed.

(38) According to certain embodiments, the operation signal generator **750** receives the logic signal **432** (e.g., Dim_on′), generates the operation signal **752** based at least in part on the logic signal **432** (e.g., Dim_on′), and outputs the operation signal **752** to the switch **730**. In some examples, the operation signal generator **750** includes a buffer. In certain examples, when the logic signal **432** (e.g., Dim_on′) changes from the logic low level to the logic high level, the operation signal **752** also changes from the logic low level to the logic high level. For example, before the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the operation signal **752** changes from the logic high level to the logic low level. As an example, when the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the operation signal **752** changes from the logic high level to the logic low level. For example, after the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the operation signal **752** changes from the logic high level to the logic low level.

(39) In some embodiments, if the operation signal **752** is at the logic low level, the switch **730** is closed, so that the gate terminal of the transistor **720** is biased to the ground voltage. For example, if the gate terminal of the transistor **720** is biased to the ground voltage, the transistor **720** is turned off so that the output current **491** that flows through the one or more LEDs **490** is not allowed to be generated (e.g., the output current **491** being equal to zero). In certain embodiments, if the operation signal **752** is at the logic high level, the switch **730** is open, so that the voltage of the gate terminal of the transistor **720** is controlled by the control signal **712**. For example, the control signal **712** is generated by the control signal generator **710** based at least in part on the logic signal **432** (e.g., Dim_on′). As an example, the control signal **712** is generated at a constant voltage level, and the constant voltage level of the control signal **712** is used by the transistor **720** to generate the output current **491** at a constant current level. For example, the constant current level of the output current **491** is determined at least in part by the constant voltage level of the control signal **712**.

(40) FIG. **8** shows simplified timing diagrams for the LED lighting system **400** if the TRIAC dimmer **470** is a leading-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **6** according to some embodiments of the present invention. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many

variations, alternatives, and modifications. As shown in FIG. **8**, the waveform **883** represents the rectified voltage **483** (e.g., VIN) as a function of time, the waveform **811** represents the logic signal **411** (e.g., Dim_on) as a function of time, the waveform **823** represents the delayed signal **523** (e.g., Dim_on_T) as a function of time, the waveform **821** represents the control signal **521** as a function of time, the waveform **832** represents the logic signal **432** (e.g., Dim_on′) as a function of time, and the waveform **891** represents the output current **491** (e.g., I.sub.led) that flows through the one or more LEDs **490** as a function of time.

(41) As shown by the waveforms **883** and **811**, if the rectified voltage **483** (e.g., VIN) is larger than a threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic high level, and if the rectified voltage **483** (e.g., VIN) is smaller than the threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic low level according to certain embodiments. As an example, the threshold voltage V.sub.x is equal to a predetermined voltage value that is selected from a range from 10 volts to 30 volts. For example, during a negative half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.1. As an example, during a positive half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.2. As shown in FIG. **8**, the phase range ϕ.sub.1 and the phase range ϕ.sub.2 are not equal, indicating the size of the waveform during the negative half cycle of the AC input voltage **472** (e.g., VAC) and the size of the waveform during the positive half cycle of the AC input voltage **472** (e.g., VAC) are different according to some embodiments.

(42) As shown by the waveforms **811** and **823**, if the mode signal **421** indicates that the TRIAC dimmer **470** is a leading-edge TRIAC dimmer, the delayed signal **523** (e.g., Dim_on_T) is generated by delaying, by a predetermined delay of time (e.g., T.sub.d), a rising edge of the logic signal **411** (e.g., Dim_on) according to some embodiments. For example, the predetermined delay of time (e.g., T.sub.d) is equal to a half cycle of the AC input voltage **472** (e.g., VAC) in time duration. As an example, the phase range ϕ.sub.2 is larger than the phase range ϕ.sub.1, and the phase range ϕ.sub.2 minus the phase range ϕ.sub.1 is equal to Δϕ. As shown by the waveforms **811**, **823** and **821**, the control signal **521** is the same as the delayed signal **523**, except that during the first half cycle of the AC input voltage **472** (e.g., VAC), the control signal **521** is the same as the logic signal **411** (e.g., Dim_on), according to certain embodiments.

(43) As shown by the waveforms **811**, **821** and **832**, if the logic signal **411** (e.g., Dim_on) or the control signal **521** is at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level, and if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic high level, the logic signal **432** (e.g., Dim_on′) is at the logic high level, according to some embodiments. For example, if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level. In certain examples, the pulse width of the logic signal **432** (e.g., Dim_on′) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the logic signal **432** (e.g., Dim_on′) during a positive half cycle of the AC input voltage **472** (e.g., VAC). As an example, during the negative half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) corresponds to the phase range ϕ.sub.1, and during the positive half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) also corresponds to the phase range ϕ.sub.1.

(44) As shown by the waveforms **832** and **891**, the logic signal **432** (e.g., Dim_on′) is used to generate the output current **491** (e.g., I.sub.led) according to certain embodiments. In some examples, the output current **491** (e.g., I.sub.led) alternates between a high current level **893** and a low current level **895** (e.g. zero) to form one or more pulses at which the output current **491** (e.g., I.sub.led) remains at the high current level **893**. For example, when the logic signal **432** (e.g., Dim_on′) changes from the logic low level to the logic high level, the output current **491** (e.g.,

I.sub.led) changes from the low current level **895** (e.g. zero) to the high current level **893**. As an example, a predetermined period of time before the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the output current **491** (e.g., I.sub.led) changes from the high current level **893** to the low current level **895** (e.g. zero). For example, the output current **491** (e.g., I.sub.led) changes from the high current level **893** to the low current level **895** (e.g. zero) when the rectified voltage **483** (e.g., VIN) changes from being larger than a threshold voltage V.sub.o to being smaller than the threshold voltage V.sub.o. As an example, the threshold voltage V.sub.o is higher than the threshold voltage V.sub.x. In certain examples, the pulse width of the output current **491** (e.g., I.sub.led) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the output current **491** (e.g., I.sub.led) during a positive half cycle of the AC input voltage **472** (e.g., VAC). For example, the time duration during which the output current **491** (e.g., I.sub.led) is at the current level **893** in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the time duration during which the output current **491** (e.g., I.sub.led) is at the current level **893** in the positive half cycle of the AC input voltage **472** (e.g., VAC) are the same. As an example, the average of the output current **491** (e.g., I.sub.led) in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the average of the output current **491** (e.g., I.sub.led) in the positive half cycle of the AC input voltage **472** (e.g., VAC) are equal, preventing flickering of the one or more LEDs **490**.

(45) FIG. **9** shows simplified timing diagrams for the LED lighting system **400** if the TRIAC dimmer **470** is a trailing-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **6** according to certain embodiments of the present invention. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **9**, the waveform **983** represents the rectified voltage **483** (e.g., VIN) as a function of time, the waveform **911** represents the logic signal **411** (e.g., Dim_on) as a function of time, the waveform **923** represents the delayed signal **523** (e.g., Dim_on_T) as a function of time, the waveform **921** represents the control signal **521** as a function of time, the waveform **932** represents the logic signal **432** (e.g., Dim_on′) as a function of time, and the waveform **991** represents the output current **491** (e.g., I.sub.led) that flows through the one or more LEDs **490** as a function of time.

(46) As shown by the waveforms **983** and **911**, if the rectified voltage **483** (e.g., VIN) is larger than a threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic high level, and if the rectified voltage **483** (e.g., VIN) is smaller than the threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic low level according to certain embodiments. As an example, the threshold voltage V.sub.x is equal to a predetermined voltage value that is selected from a range from 10 volts to 30 volts. For example, during a negative half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.1. As an example, during a positive half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.2. As shown in FIG. **9**, the phase range ϕ.sub.1 and the phase range ϕ.sub.2 are not equal, indicating the size of the waveform during the negative half cycle of the AC input voltage **472** (e.g., VAC) and the size of the waveform during the positive half cycle of the AC input voltage **472** (e.g., VAC) are different according to some embodiments.

(47) As shown by the waveforms **911** and **923**, if the mode signal **421** indicates that the TRIAC dimmer **470** is a trailing-edge TRIAC dimmer, the delayed signal **523** (e.g., Dim_on_T) is generated by delaying, by a predetermined delay of time (e.g., T.sub.d), a falling edge of the logic signal **411** (e.g., Dim_on) according to some embodiments. For example, the predetermined delay of time (e.g., T.sub.d) is equal to a half cycle of the AC input voltage **472** (e.g., VAC) in time duration. As an example, the phase range ϕ.sub.2 is larger than the phase range ϕ.sub.1, and the phase range ϕ.sub.2 minus the phase range ϕ.sub.1 is equal to Δϕ. As shown by the waveforms **911**,

923 and **921**, the control signal **521** is the same as the delayed signal **523**, except that during the first half cycle of the AC input voltage **472** (e.g., VAC), the control signal **521** is the same as the logic signal **411** (e.g., Dim_on), according to certain embodiments.
(48) As shown by the waveforms **911**, **921** and **932**, if the logic signal **411** (e.g., Dim_on) or the control signal **521** is at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level, and if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic high level, the logic signal **432** (e.g., Dim_on′) is at the logic high level, according to some embodiments. For example, if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level. In certain examples, the pulse width of the logic signal **432** (e.g., Dim_on′) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the logic signal **432** (e.g., Dim_on′) during a positive half cycle of the AC input voltage **472** (e.g., VAC). As an example, during the negative half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) corresponds to the phase range ϕ.sub.1, and during the positive half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) also corresponds to the phase range ϕ.sub.1.
(49) As shown by the waveforms **932** and **991**, the logic signal **432** (e.g., Dim_on′) is used to generate the output current **491** (e.g., bed) according to certain embodiments. In some examples, the output current **491** (e.g., I.sub.led) alternates between a high current level **993** and a low current level **995** (e.g. zero) to form one or more pulses at which the output current **491** (e.g., I.sub.led) remains at the high current level **993**. For example, a predetermined period of time after the logic signal **432** (e.g., Dim_on′) changes from the logic low level to the logic high level, the output current **491** (e.g., I.sub.led) changes from the low current level **995** (e.g. zero) to the high current level **993**. As an example, the output current **491** (e.g., I.sub.led) changes from the low current level **995** (e.g. zero) to the high current level **993** when the rectified voltage **483** (e.g., VIN) changes from being smaller than a threshold voltage V.sub.o to being larger than the threshold voltage V.sub.o. As an example, the threshold voltage V.sub.o is higher than the threshold voltage V.sub.x. For example, when the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the output current **491** (e.g., I.sub.led) changes from the high current level **993** to the low current level **995** (e.g. zero). In certain examples, the pulse width of the output current **491** (e.g., I.sub.led) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the output current **491** (e.g., I.sub.led) during a positive half cycle of the AC input voltage **472** (e.g., VAC). For example, the time duration during which the output current **491** (e.g., I.sub.led) is at the current level **993** in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the time duration during which the output current **491** (e.g., I.sub.led) is at the current level **993** in the positive half cycle of the AC input voltage **472** (e.g., VAC) are the same. As an example, the average of the output current **491** (e.g., I.sub.led) in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the average of the output current **491** (e.g., I.sub.led) in the positive half cycle of the AC input voltage **472** (e.g., VAC) are equal, preventing flickering of the one or more LEDs **490**.
(50) FIG. **10** shows simplified timing diagrams for the LED lighting system **400** if the TRIAC dimmer **470** is a leading-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **7** according to some embodiments of the present invention. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **10**, the waveform **1083** represents the rectified voltage **483** (e.g., VIN) as a function of time, the waveform **1011** represents the logic signal **411** (e.g., Dim_on) as a function of time, the waveform **1023** represents the delayed signal **523** (e.g., Dim_on_T) as a function of time, the waveform **1021** represents the control signal **521** as a function of time, the waveform **1032** represents the logic signal **432** (e.g., Dim_on′) as a function of time, the waveform **1052** represents the operation signal **752** as a function of time, and the

waveform **1091** represents the output current **491** (e.g., I.sub.led) that flows through the one or more LEDs **490** as a function of time.
(51) As shown by the waveforms **1083** and **1011**, if the rectified voltage **483** (e.g., VIN) is larger than a threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic high level, and if the rectified voltage **483** (e.g., VIN) is smaller than the threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic low level according to certain embodiments. As an example, the threshold voltage V.sub.x is equal to a predetermined voltage value that is selected from a range from 10 volts to 30 volts. For example, during a negative half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.1. As an example, during a positive half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.2. As shown in FIG. **10**, the phase range ϕ.sub.1 and the phase range ϕ.sub.2 are not equal, indicating the size of the waveform during the negative half cycle of the AC input voltage **472** (e.g., VAC) and the size of the waveform during the positive half cycle of the AC input voltage **472** (e.g., VAC) are different according to some embodiments.
(52) As shown by the waveforms **1011** and **1023**, if the mode signal **421** indicates that the TRIAC dimmer **470** is a leading-edge TRIAC dimmer, the delayed signal **523** (e.g., Dim_on_T) is generated by delaying, by a predetermined delay of time (e.g., T.sub.d), a rising edge of the logic signal **411** (e.g., Dim_on) according to some embodiments. For example, the predetermined delay of time (e.g., T.sub.d) is equal to a half cycle of the AC input voltage **472** (e.g., VAC) in time duration. As an example, the phase range ϕ.sub.2 is larger than the phase range ϕ.sub.1, and the phase range ϕ.sub.2 minus the phase range ϕ.sub.1 is equal to Δϕ. As shown by the waveforms **1011**, **1023** and **1021**, the control signal **521** is the same as the delayed signal **523**, except that during the first half cycle of the AC input voltage **472** (e.g., VAC), the control signal **521** is the same as the logic signal **411** (e.g., Dim_on), according to certain embodiments.
(53) As shown by the waveforms **1011**, **1021** and **1032**, if the logic signal **411** (e.g., Dim_on) or the control signal **521** is at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level, and if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic high level, the logic signal **432** (e.g., Dim_on′) is at the logic high level, according to some embodiments. For example, if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level. In certain examples, the pulse width of the logic signal **432** (e.g., Dim_on′) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the logic signal **432** (e.g., Dim_on′) during a positive half cycle of the AC input voltage **472** (e.g., VAC). As an example, during the negative half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) corresponds to the phase range ϕ.sub.1, and during the positive half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) also corresponds to the phase range ϕ.sub.1.
(54) As shown by the waveforms **1032** and **1052**, the operation signal **752** is generated based at least in part on the logic signal **432** (e.g., Dim_on′) according to certain embodiments. In some examples, when the logic signal **432** (e.g., Dim_on′) changes from the logic low level to the logic high level, the operation signal **752** also changes from the logic low level to the logic high level. In certain examples, before, when, or after the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the operation signal **752** changes from the logic high level to the logic low level. As an example, when the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the operation signal **752** also changes from the logic high level to the logic low level.
(55) As shown by the waveforms **1052** and **1091**, the operation signal **752** is used to generate the output current **491** (e.g., I.sub.led) according to some embodiments. In some examples, the output

current **491** (e.g., I.sub.led) alternates between a high current level **1093** and a low current level **1095** (e.g. zero) to form one or more pulses at which the output current **491** (e.g., I.sub.led) remains at the high current level **1093**. For example, when the operation signal **752** changes from the logic low level to the logic high level, the output current **491** (e.g., I.sub.led) changes from the low current level **1095** (e.g. zero) to the high current level **1093**. As an example, a predetermined period of time before the operation signal **752** changes from the logic high level to the logic low level, the output current **491** (e.g., I.sub.led) changes from the high current level **1093** to the low current level **1095** (e.g. zero). For example, the output current **491** (e.g., I.sub.led) changes from the high current level **1093** to the low current level **1095** (e.g. zero) when the rectified voltage **483** (e.g., VIN) changes from being larger than a threshold voltage V.sub.o to being smaller than the threshold voltage V.sub.o. As an example, the threshold voltage V.sub.o is higher than the threshold voltage V.sub.x. In certain examples, the pulse width of the output current **491** (e.g., I.sub.led) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the output current **491** (e.g., I.sub.led) during a positive half cycle of the AC input voltage **472** (e.g., VAC). For example, the time duration during which the output current **491** (e.g., I.sub.led) is at the current level **1093** in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the time duration during which the output current **491** (e.g., bed) is at the current level **1093** in the positive half cycle of the AC input voltage **472** (e.g., VAC) are the same. As an example, the average of the output current **491** (e.g., I.sub.led) in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the average of the output current **491** (e.g., I.sub.led) in the positive half cycle of the AC input voltage **472** (e.g., VAC) are equal, preventing flickering of the one or more LEDs **490**.

(56) FIG. **11** shows simplified timing diagrams for the LED lighting system **400** if the TRIAC dimmer **470** is a trailing-edge TRIAC dimmer as shown in FIG. **4**, FIG. **5** and FIG. **7** according to certain embodiments of the present invention. These diagrams are merely examples, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. As shown in FIG. **11**, the waveform **1183** represents the rectified voltage **483** (e.g., VIN) as a function of time, the waveform **1111** represents the logic signal **411** (e.g., Dim_on) as a function of time, the waveform **1123** represents the delayed signal **523** (e.g., Dim_on_T) as a function of time, the waveform **1121** represents the control signal **521** as a function of time, the waveform **1132** represents the logic signal **432** (e.g., Dim_on′) as a function of time, and the waveform **1191** represents the output current **491** (e.g., I.sub.led) that flows through the one or more LEDs **490** as a function of time.

(57) As shown by the waveforms **1183** and **1111**, if the rectified voltage **483** (e.g., VIN) is larger than a threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic high level, and if the rectified voltage **483** (e.g., VIN) is smaller than the threshold voltage V.sub.x, the logic signal **411** (e.g., Dim_on) is at a logic low level according to certain embodiments. As an example, the threshold voltage V.sub.x is equal to a predetermined voltage value that is selected from a range from 10 volts to 30 volts. For example, during a negative half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.1. As an example, during a positive half cycle of the AC input voltage **472** (e.g., VAC), the logic signal **411** (e.g., Dim_on) remains at the logic high level during a time duration that corresponds to a phase range ϕ.sub.2. As shown in FIG. **11**, the phase range ϕ.sub.1 and the phase range ϕ.sub.2 are not equal, indicating the size of the waveform during the negative half cycle of the AC input voltage **472** (e.g., VAC) and the size of the waveform during the positive half cycle of the AC input voltage **472** (e.g., VAC) are different according to some embodiments.

(58) As shown by the waveforms **1111** and **1123**, if the mode signal **421** indicates that the TRIAC dimmer **470** is a trailing-edge TRIAC dimmer, the delayed signal **523** (e.g., Dim_on_T) is generated by delaying, by a predetermined delay of time (e.g., T.sub.d), a falling edge of the logic signal **411** (e.g., Dim_on) according to some embodiments. For example, the predetermined delay

of time (e.g., T.sub.d) is equal to a half cycle of the AC input voltage **472** (e.g., VAC) in time duration. As an example, the phase range ϕ.sub.2 is larger than the phase range ϕ.sub.1, and the phase range ϕ.sub.2 minus the phase range ϕ.sub.1 is equal to Δϕ. As shown by the waveforms **1111**, **1123** and **1121**, the control signal **521** is the same as the delayed signal **523**, except that during the first half cycle of the AC input voltage **472** (e.g., VAC), the control signal **521** is the same as the logic signal **411** (e.g., Dim_on), according to certain embodiments.

(59) As shown by the waveforms **1111**, **1121** and **1132**, if the logic signal **411** (e.g., Dim_on) or the control signal **521** is at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level, and if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic high level, the logic signal **432** (e.g., Dim_on′) is at the logic high level, according to some embodiments. For example, if the logic signal **411** (e.g., Dim_on) and the control signal **521** both are at the logic low level, the logic signal **432** (e.g., Dim_on′) is at the logic low level. In certain examples, the pulse width of the logic signal **432** (e.g., Dim_on′) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the logic signal **432** (e.g., Dim_on′) during a positive half cycle of the AC input voltage **472** (e.g., VAC). As an example, during the negative half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) corresponds to the phase range ϕ.sub.1, and during the positive half cycle of the AC input voltage **472** (e.g., VAC), the pulse width of the logic signal **432** (e.g., Dim_on′) also corresponds to the phase range ϕ.sub.1.

(60) As shown by the waveforms **1132** and **1152**, the operation signal **752** is generated based at least in part on the logic signal **432** (e.g., Dim_on′) according to certain embodiments. In some examples, when the logic signal **432** (e.g., Dim_on′) changes from the logic low level to the logic high level, the operation signal **752** also changes from the logic low level to the logic high level. In certain examples, before, when, or after the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the operation signal **752** changes from the logic high level to the logic low level. As an example, when the logic signal **432** (e.g., Dim_on′) changes from the logic high level to the logic low level, the operation signal **752** also changes from the logic high level to the logic low level.

(61) As shown by the waveforms **1152** and **1191**, the operation signal **752** is used to generate the output current **491** (e.g., I.sub.led) according to some embodiments. In some examples, the output current **491** (e.g., I.sub.led) alternates between a high current level **1193** and a low current level **1195** (e.g. zero) to form one or more pulses at which the output current **491** (e.g., I.sub.led) remains at the high current level **1193**. For example, when the operation signal **752** changes from the logic high level to the logic low level, the output current **491** (e.g., I.sub.led) changes from the high current level **1193** to the low current level **1195** (e.g. zero). As an example, a predetermined period of time after the operation signal **752** changes from the logic low level to the logic high level, the output current **491** (e.g., I.sub.led) changes from the low current level **1195** (e.g. zero) to the high current level **1193**. For example, the output current **491** (e.g., I.sub.led) changes from the low current level **1195** (e.g. zero) to the high current level **1193** when the rectified voltage **483** (e.g., VIN) changes from being smaller than a threshold voltage V.sub.o to being larger than the threshold voltage V.sub.o. As an example, the threshold voltage V.sub.o is higher than the threshold voltage V.sub.x. In certain examples, the pulse width of the output current **491** (e.g., I.sub.led) during a negative half cycle of the AC input voltage **472** (e.g., VAC) is equal to the pulse width of the output current **491** (e.g., I.sub.led) during a positive half cycle of the AC input voltage **472** (e.g., VAC). For example, the time duration during which the output current **491** (e.g., I.sub.led) is at the current level **1193** in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the time duration during which the output current **491** (e.g., I.sub.led) is at the current level **1193** in the positive half cycle of the AC input voltage **472** (e.g., VAC) are the same. As an example, the average of the output current **491** (e.g., I.sub.led) in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the average of the output current **491** (e.g., I.sub.led) in the positive half cycle

of the AC input voltage **472** (e.g., VAC) are equal, preventing flickering of the one or more LEDs **490**.
(62) FIG. **12** is a simplified diagram showing a method for the LED lighting system **400** as shown in FIG. **4** and FIG. **5** according to some embodiments of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The method **1200** includes a process **1210** for generating the logic signal **411** (e.g., Dim_on) based at least in part on the sensing signal **461** (e.g., LS), a process **1220** for generating the mode signal **421** that indicates whether the TRIAC dimmer **470** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based at least in part on the sensing signal **461** (e.g., LS), a process **1230** for generating the logic signal **432** (e.g., Dim_on′) based at least in part on the logic signal **411** (e.g., Dim_on) and the mode signal **421**, and a process **1240** for controlling the output current **491** that flows through the one or more LEDs **490** based at least in part on the logic signal **432** (e.g., Dim_on′).
(63) At the process **1210**, the logic signal **411** (e.g., Dim_on) is generated based at least in part on the sensing signal **461** (e.g., LS) according to certain embodiments. At the process **1220**, the mode signal **421** is generated based at least in part on the sensing signal **461** (e.g., LS) to indicate whether the TRIAC dimmer **470** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer according to some embodiments.
(64) At the process **1230**, the logic signal **432** (e.g., Dim_on′) is generated based at least in part on the logic signal **411** (e.g., Dim_on) and the mode signal **421** according to certain embodiments. In some examples, a rising edge and/or a falling edge of the logic signal **411** (e.g., Dim_on) is detected. In certain examples, using the mode signal **421** and the logic signal **411** (e.g., Dim_on), the control signal **521** is generated based at least in part on the detected rising edge of the logic signal **411** (e.g., Dim_on) or the detected falling edge of the logic signal **411** (e.g., Dim_on).
(65) In some embodiments, using the mode signal **421**, the delayed signal **523** (e.g., Dim_on_T) is generated based at least in part on the detected rising edge of the logic signal **411** (e.g., Dim_on) or the detected falling edge of the logic signal **411** (e.g., Dim_on). For example, if the mode signal **421** indicates that the TRIAC dimmer **470** is a leading-edge TRIAC dimmer, the delay sub-unit **522** generates the delayed signal **523** (e.g., Dim_on_T) by delaying, by a predetermined delay of time, the detected rising edge of the logic signal **411** (e.g., Dim_on). As an example, if the mode signal **421** indicates that the TRIAC dimmer **470** is a trailing-edge TRIAC dimmer, the delay sub-unit **522** generates the delayed signal **523** (e.g., Dim_on_T) by delaying, by the predetermined delay of time, the detected falling edge of the logic signal **411** (e.g., Dim_on).
(66) In certain embodiments, the control signal **521** is generated based at least in part on the delayed signal **523** and the logic signal **411** (e.g., Dim_on). In some examples, the control signal **521** is the same as the delayed signal **523**, except that during the first half cycle of the AC input voltage **472** (e.g., VAC), the control signal **521** is the same as the logic signal **411** (e.g., Dim_on). For example, the first half cycle of the AC input voltage **472** (e.g., VAC) is either a positive half cycle or a negative half cycle of the AC input voltage **472** (e.g., VAC). As an example, the first half cycle of the AC input voltage **472** (e.g., VAC) occurs immediately after the system **400** is powered on.
(67) At the process **1240**, the output current **491** that flows through the one or more LEDs **490** is controlled based at least in part on the logic signal **432** (e.g., Dim_on′) according to some embodiments. For example, if the output current **491** that flows through the one or more LEDs **490** is not allowed to be generated, the output current **491** is equal to zero in magnitude.
(68) FIG. **13** is a simplified diagram showing a method for the LED lighting system **400** as shown in FIG. **4** and FIG. **5** according to certain embodiments of the present invention. This diagram is merely an example, which should not unduly limit the scope of the claims. One of ordinary skill in the art would recognize many variations, alternatives, and modifications. The method **1300** includes a process **1310** for generating the sensing signal **461** (e.g., LS) that represents the rectified

voltage **483** (e.g., VIN), a process **1320** for determining whether the TRIAC dimmer **470** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based at least in part on the sensing signal **461** (e.g., LS) in order to generate the mode signal **421**, a process **1330** for generating the delayed signal **523** (e.g., Dim_on_T) by delaying, by a predetermined delay of time (e.g., T.sub.d), the rising edge of the logic signal **411** (e.g., Dim_on), a process **1332** for not allowing the output current **491** to be generated from at least the falling edge of the logic signal **411** (e.g., Dim_on) until the delayed rising edge of the logic signal **411** (e.g., Dim_on), a process **1340** for generating the delayed signal **523** (e.g., Dim_on_T) by delaying, by a predetermined delay of time (e.g., T.sub.d), the falling edge of the logic signal **411** (e.g., Dim_on), a process **1342** for not allowing the output current **491** to be generated from the delayed falling edge of the logic signal **411** (e.g., Dim_on) until at least the rising edge of the logic signal **411** (e.g., Dim_on), a process **1350** for operating the LED lighting system **400** without flickering of the one or more LEDs **490**.

(69) At the process **1310**, the sensing signal **461** (e.g., LS) that represents the rectified voltage **483** (e.g., VIN) is generated according to some embodiments. At the process **1320**, whether the TRIAC dimmer **470** is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer is determined based at least in part on the sensing signal **461** (e.g., LS) in order to generate the mode signal **421** according to certain embodiments. In some examples, if the TRIAC dimmer **470** is determined to be a leading-edge TRIAC dimmer, the processes **1330**, **1332**, and **1350** are performed. In certain examples, if the TRIAC dimmer **470** is determined to be a trailing-edge TRIAC dimmer, the processes **1340**, **1342**, and **1350** are performed.

(70) At the process **1330**, the delayed signal **523** (e.g., Dim_on_T) is generated by delaying, by a predetermined delay of time (e.g., T.sub.d), the rising edge of the logic signal **411** (e.g., Dim_on) according to some embodiments. For example, the predetermined delay of time (e.g., T.sub.d) is equal to a half cycle of the AC input voltage **472** (e.g., VAC) in time duration. At the process **1332**, the output current **491** is not allowed to be generated from at least the falling edge of the logic signal **411** (e.g., Dim_on) until the delayed rising edge of the logic signal **411** (e.g., Dim_on) according to certain embodiments. As an example, if the output current **491** that flows through the one or more LEDs **490** is not allowed to be generated, the output current **491** is equal to zero in magnitude.

(71) At the process **1340**, the delayed signal **523** (e.g., Dim_on_T) is generated by delaying, by a predetermined delay of time (e.g., T.sub.d), the falling edge of the logic signal **411** (e.g., Dim_on) according to some embodiments. For example, the predetermined delay of time (e.g., T.sub.d) is equal to a half cycle of the AC input voltage **472** (e.g., VAC) in time duration. At the process **1342**, the output current **491** is not allowed to be generated from the delayed falling edge of the logic signal **411** (e.g., Dim_on) until at least the rising edge of the logic signal **411** (e.g., Dim_on) according to certain embodiments. As an example, if the output current **491** that flows through the one or more LEDs **490** is not allowed to be generated, the output current **491** is equal to zero in magnitude.

(72) At the process **1350**, the LED lighting system **400** operates without flickering of the one or more LEDs **490**. For example, the size of the waveform during the negative half cycle of the AC input voltage **472** (e.g., VAC) and the size of the waveform during the positive half cycle of the AC input voltage **472** (e.g., VAC) are different. As an example, the average of the output current **491** in the negative half cycle of the AC input voltage **472** (e.g., VAC) and the average of the output current **491** in the positive half cycle of the AC input voltage **472** (e.g., VAC) are equal, preventing flickering of the one or more LEDs **490**.

(73) Certain embodiments of the present invention prevent flickering of the one or more LEDs even if the waveform during the positive half cycle of the AC input voltage and the waveform during the negative half cycle of the AC input voltage are significantly different. Some embodiments of the present invention improve effect of the dimming control and also improve compatibility of the TRIAC dimmer, without increasing bill of materials (BOM) for the

components that are external to the chip.

(74) According to some embodiments, a system for controlling one or more light emitting diodes includes: a phase detector configured to process information associated with a rectified voltage generated by a rectifier and related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the phase detector being further configured to generate a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; a mode detector configured to process information associated with the rectified voltage, determine whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage, and generate a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; a modified signal generator configured to receive the phase detection signal from the phase detector and the mode detection signal from the mode detector, modify the phase detection signal based at least in part on the mode detection signal, and generate a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; and a current controller configured to receive the modified signal, the current controller being further configured to control, based at least in part of the modified signal, a first current flowing through one or more light emitting diodes configured to receive the rectified voltage; wherein: the first time duration and the second time duration are different in magnitude; and the third time duration and the fourth time duration are the same in magnitude. For example, the system for controlling one or more light emitting diodes is implemented according to at least FIG. **4**.

(75) In certain examples, a first average of the first current corresponding to the first half cycle of the AC voltage and a second average of the first current corresponding to the second half cycle of the AC voltage are equal in magnitude. In some examples, the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; and the fourth time duration is smaller than the second duration in magnitude. In certain examples, the first time duration is larger than the second time duration in magnitude; the third time duration is smaller than the first time duration in magnitude; and the fourth time duration is equal to the second duration in magnitude.

(76) In some examples, the modified signal generator includes a control signal generator configured to: process information associated with the phase detection signal; delay, by a predetermined delay of time, one or more rising edges of the phase detection signal or one or more falling edges of the phase detection signal based at least in part on the mode detection signal; and generate a control signal based at least in part on the one or more delayed rising edges or the one or more delayed falling edges. In certain examples, the control signal generator is further configured to: delay, by the predetermined delay of time, the one or more rising edges of the phase detection signal if the mode detection signal indicates that the TRIAC dimmer is the leading-edge TRIAC dimmer; and delay, by the predetermined delay of time, the one or more falling edges of the phase detection signal if the mode detection signal indicates that the TRIAC dimmer is the trailing-edge TRIAC dimmer. In some examples, the control signal generator is further configured to generate the control signal based at least in part on the one or more delayed rising edges or the one or more delayed falling edges and also based at least in part on the phase detection signal.

(77) In certain examples, wherein the control signal generator includes a delayed signal generator configured to: receive the mode detection signal; delay, by the predetermined delay of time, the one or more rising edges of the phase detection signal or the one or more falling edges of the phase detection signal based at least in part on the mode detection signal; and generate a delayed signal

based at least in part on the one or more delayed rising edges or the one or more delayed falling edges. In some examples, the control signal generator further includes a signal controller configured to receive the delayed signal and the phase detection signal and generate the control signal based at least in part on the delayed signal and the phase detection signal. In certain examples, the control signal generator is further configured to generate the control signal that is the same as the delayed signal, except that during the first half cycle of the AC input voltage, the control signal is the same as the phase detection signal.

(78) In some examples, the modified signal generator further includes an output signal generator configured to receive the control signal and the phase detection signal and generate the modified signal based at least in part on the control signal and the phase detection signal. In certain examples, the output signal generator includes an AND gate, the AND gate being configured to receive the control signal and the phase detection signal and generate the modified signal based at least in part on the control signal and the phase detection signal. In some examples, the predetermined delay of time is equal to the first half cycle of the AC voltage in duration; and the predetermined delay of time is equal to the second half cycle of the AC voltage in duration.

(79) In certain examples, the current controller includes: a control signal generator configured to receive the modified signal and generate a drive signal based at least in part on the modified signal; a switch configured to receive the modified signal and become closed or open based at least in part on the modified signal; and a transistor including a first transistor terminal, a second transistor terminal and a third transistor terminal, the first transistor terminal being coupled to the control signal generator and the switch, the second transistor terminal being coupled to the one or more light emitting diodes. In some examples, the switch is further configured to be: open if the modified signal is at a first logic level; and closed if the modified signal is at a second logic level; wherein the first logic level and the second logic level are different. In certain examples, the modified signal is at the first logic level during the third time duration within the first half cycle of the AC voltage; and the modified signal is at the second logic level outside the third time duration within the first half cycle of the AC voltage. In some examples, the modified signal is at the first logic level during the fourth time duration within the second half cycle of the AC voltage; and the modified signal is at the second logic level outside the fourth time duration within the second half cycle of the AC voltage. In certain examples, the first logic level is a logic high level; and the second logic level is a logic low level. In some examples, if the switch is closed, the first current flowing through the one or more light emitting diodes is equal to zero in magnitude; and if the switch is open, the first current flowing through the one or more light emitting diodes is equal to a predetermined value in magnitude based at least in part on the drive signal; wherein the predetermined value is larger than zero.

(80) In certain examples, the current controller further includes a resistor including a first resistor terminal and a second resistor terminal; and the switch including a first switch terminal and a second switch terminal; wherein: the first resistor terminal is connected to the third transistor terminal; the second resistor terminal is biased to a ground voltage; the first switch terminal is connected to the first transistor terminal; and the second switch terminal is biased to the ground voltage.

(81) In some examples, the current controller includes: a control signal generator configured to receive the modified signal and generate a drive signal based at least in part on the modified signal; an operation signal generator configured to receive the modified signal and generate an operation signal based at least in part on the modified signal; a switch configured to receive the operation signal and become closed or open based at least in part on the operation signal; and a transistor including a first transistor terminal, a second transistor terminal and a third transistor terminal, the first transistor terminal being coupled to the control signal generator and the switch, the second transistor terminal being coupled to the one or more light emitting diodes. In certain examples, the switch is further configured to be: open if the operation signal is at a first logic level; and closed if

the operation signal is at a second logic level; wherein the first logic level and the second logic level are different. In some examples, the operation signal generator is further configured to: change the operation signal from the second logic level to the first logic level at a same time as the modified signal; and change the operation signal from the first logic level to the second logic level at a different time from the modified signal. In certain examples, the operation signal generator is further configured to: change the operation signal from the second logic level to the first logic level at a same time as the modified signal; and change the operation signal from the first logic level to the second logic level at a same time from the modified signal.
(82) In some examples, the system for controlling one or more light emitting diodes further includes: a bleeder current controller and generator configured to receive the mode detection signal and generate a bleeder current based at least in part on the mode selection signal to ensure that a second current flowing through the TRIAC dimmer does not fall below a holding current of the TRIAC dimmer. In certain examples, the system for controlling one or more light emitting diodes further includes: a voltage detector configured to receive the rectified voltage and generate a sensing signal based at least in part on the rectified voltage; wherein the phase detector is further configured to: receive the sensing signal; and generate the phase detection signal based at least in part on the sensing signal; wherein the mode detector is further configured to: receive the sensing signal; and generate the mode detection signal based at last in part on the sensing signal. In some examples, the voltage detector includes a voltage divider including a first resistor and a second resistor.
(83) According to certain embodiments, a system for controlling one or more light emitting diodes includes: a phase detector configured to process information associated with a rectified voltage generated by a rectifier and related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the signal detector being further configured to generate a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; a mode detector configured to process information associated with the rectified voltage, determine whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage, and generate a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; and a modified signal generator configured to receive the phase detection signal from the phase detector and the mode detection signal from the mode detector, the modified signal generator being further configured to generate, based at least in part on the phase detection signal and the mode detection signal, a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; wherein: the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; the fourth time duration is smaller than the second duration in magnitude; and the third time duration and the fourth time duration are equal in magnitude. For example, the system for controlling one or more light emitting diodes is implemented according to at least FIG. **4**.
(84) According to some embodiments, a method for controlling one or more light emitting diodes includes: processing information associated with a rectified voltage related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage; generating a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the

predetermined threshold; determining whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage; generating a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; receiving the phase detection signal and the mode detection signal; modifying the phase detection signal based at least in part on the mode detection signal; generating a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; receiving the modified signal; and controlling, based at least in part of the modified signal, a first current flowing through one or more light emitting diodes configured to receive the rectified voltage; wherein: the first time duration and the second time duration are different in magnitude; and the third time duration and the fourth time duration are the same in magnitude. For example, the method for controlling one or more light emitting diodes is implemented according to at least FIG. **4**.
(85) According to certain embodiments, a method for controlling one or more light emitting diodes includes: processing information associated with a rectified voltage related to a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage; generating a phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; determining whether the TRIAC dimmer is a leading-edge TRIAC dimmer or a trailing-edge TRIAC dimmer based on at least information associated with the rectified voltage; generating a mode detection signal that indicates whether the TRIAC dimmer is the leading-edge TRIAC dimmer or the trailing-edge TRIAC dimmer; receiving the phase detection signal and the mode detection signal; and generating, based at least in part on the phase detection signal and the mode detection signal, a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; wherein: the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; the fourth time duration is smaller than the second duration in magnitude; and the third time duration and the fourth time duration are equal in magnitude. For example, the method for controlling one or more light emitting diodes is implemented according to at least FIG. **4**.
(86) For example, some or all components of various embodiments of the present invention each are, individually and/or in combination with at least another component, implemented using one or more software components, one or more hardware components, and/or one or more combinations of software and hardware components. As an example, some or all components of various embodiments of the present invention each are, individually and/or in combination with at least another component, implemented in one or more circuits, such as one or more analog circuits and/or one or more digital circuits. For example, various embodiments and/or examples of the present invention can be combined.
(87) Although specific embodiments of the present invention have been described, it will be understood by those of skill in the art that there are other embodiments that are equivalent to the described embodiments. Accordingly, it is to be understood that the invention is not to be limited by the specific illustrated embodiments.

Claims

1. A system for controlling one or more light emitting diodes, the system comprising: a modified signal generator configured to receive a phase detection signal associated with a rectified voltage and a mode detection signal associated with a TRIAC dimmer, the rectified voltage corresponding

to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold, modify the phase detection signal based at least in part on the mode detection signal, and generate a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; and a current controller configured to receive the modified signal, the current controller being further configured to control, based at least in part of the modified signal, a first current flowing through the one or more light emitting diodes configured to receive the rectified voltage; wherein: the first time duration and the second time duration are different in magnitude; and the third time duration and the fourth time duration are the same in magnitude.

2. The system of claim 1 wherein a first average of the first current corresponding to the first half cycle of the AC voltage and a second average of the first current corresponding to the second half cycle of the AC voltage are equal in magnitude.

3. The system of claim 1 wherein: the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; and the fourth time duration is smaller than the second time duration in magnitude.

4. The system of claim 1 wherein: the first time duration is larger than the second time duration in magnitude; the third time duration is smaller than the first time duration in magnitude; and the fourth time duration is equal to the second time duration in magnitude.

5. The system of claim 1 wherein the modified signal generator includes: a control signal generator configured to: process information associated with the phase detection signal; delay, by a predetermined delay of time, one or more rising edges of the phase detection signal or one or more falling edges of the phase detection signal based at least in part on the mode detection signal; and generate a control signal based at least in part on the one or more delayed rising edges or the one or more delayed falling edges.

6. The system of claim 5 wherein the control signal generator is further configured to: delay, by the predetermined delay of time, the one or more rising edges of the phase detection signal if the mode detection signal indicates that the TRIAC dimmer is a leading-edge TRIAC dimmer; and delay, by the predetermined delay of time, the one or more falling edges of the phase detection signal if the mode detection signal indicates that the TRIAC dimmer is a trailing-edge TRIAC dimmer.

7. The system of claim 5 wherein the control signal generator is further configured to generate the control signal based at least in part on the one or more delayed rising edges or the one or more delayed falling edges and also based at least in part on the phase detection signal.

8. The system of claim 5 wherein the control signal generator includes: a delayed signal generator configured to: receive the mode detection signal; delay, by the predetermined delay of time, the one or more rising edges of the phase detection signal or the one or more falling edges of the phase detection signal based at least in part on the mode detection signal; and generate a delayed signal based at least in part on the one or more delayed rising edges or the one or more delayed falling edges.

9. The system of claim 8 wherein the control signal generator further includes a signal controller configured to receive the delayed signal and the phase detection signal and generate the control signal based at least in part on the delayed signal and the phase detection signal.

10. The system of claim 9 wherein the control signal generator is further configured to generate the control signal that is the same as the delayed signal, except that during the first half cycle of the AC voltage, the control signal is the same as the phase detection signal.

11. The system of claim 5 wherein the modified signal generator further includes an output signal generator configured to receive the control signal and the phase detection signal and generate the

modified signal based at least in part on the control signal and the phase detection signal.
12. The system of claim 11 wherein the output signal generator includes an AND gate, the AND gate being configured to receive the control signal and the phase detection signal and generate the modified signal based at least in part on the control signal and the phase detection signal.
13. The system of claim 5 wherein: the predetermined delay of time is equal to the first half cycle of the AC voltage in duration.
14. The system of claim 1 wherein the current controller includes: a control signal generator configured to receive the modified signal and generate a drive signal based at least in part on the modified signal; a switch configured to receive the modified signal and become closed or open based at least in part on the modified signal; and a transistor including a first transistor terminal, a second transistor terminal and a third transistor terminal, the first transistor terminal being coupled to the control signal generator and the switch, the second transistor terminal being coupled to the one or more light emitting diodes.
15. The system of claim 14 wherein the switch is further configured to be: open if the modified signal is at a first logic level; and closed if the modified signal is at a second logic level; wherein the first logic level and the second logic level are different.
16. The system of claim 15 wherein: the modified signal is at the first logic level during the third time duration within the first half cycle of the AC voltage; and the modified signal is at the second logic level outside the third time duration within the first half cycle of the AC voltage.
17. The system of claim 16 wherein: the modified signal is at the first logic level during the fourth time duration within the second half cycle of the AC voltage; and the modified signal is at the second logic level outside the fourth time duration within the second half cycle of the AC voltage.
18. The system of claim 15 wherein: the first logic level is a logic high level; and the second logic level is a logic low level.
19. The system of claim 15 wherein: if the switch is closed, the first current flowing through the one or more light emitting diodes is equal to zero in magnitude; and if the switch is open, the first current flowing through the one or more light emitting diodes is equal to a predetermined value in magnitude based at least in part on the drive signal; wherein the predetermined value is larger than zero.
20. The system of claim 14 wherein: the current controller further includes a resistor including a first resistor terminal and a second resistor terminal; and the switch including a first switch terminal and a second switch terminal; wherein: the first resistor terminal is connected to the third transistor terminal; the second resistor terminal is biased to a ground voltage; the first switch terminal is connected to the first transistor terminal; and the second switch terminal is biased to the ground voltage.
21. The system of claim 1 wherein the current controller includes: a control signal generator configured to receive the modified signal and generate a drive signal based at least in part on the modified signal; an operation signal generator configured to receive the modified signal and generate an operation signal based at least in part on the modified signal; a switch configured to receive the operation signal and become closed or open based at least in part on the operation signal; and a transistor including a first transistor terminal, a second transistor terminal and a third transistor terminal, the first transistor terminal being coupled to the control signal generator and the switch, the second transistor terminal being coupled to the one or more light emitting diodes.
22. The system of claim 21 wherein the switch is further configured to be: open if the operation signal is at a first logic level; and closed if the operation signal is at a second logic level; wherein the first logic level and the second logic level are different.
23. The system of claim 22 wherein the operation signal generator is further configured to: change the operation signal from the second logic level to the first logic level at a same time as the modified signal; and change the operation signal from the first logic level to the second logic level at a different time from the modified signal.

24. The system of claim 22 wherein the operation signal generator is further configured to: change the operation signal from the second logic level to the first logic level at a same time as the modified signal; and change the operation signal from the first logic level to the second logic level at a same time from the modified signal.
25. The system of claim 1, and further comprising: a bleeder current controller and generator configured to receive the mode detection signal and generate a bleeder current based at least in part on the mode selection signal to ensure that a second current flowing through the TRIAC dimmer does not fall below a holding current of the TRIAC dimmer.
26. The system of claim 1, and further comprising: a voltage detector configured to receive the rectified voltage and generate a sensing signal based at least in part on the rectified voltage; and a phase detector configured to: receive the sensing signal; and generate the phase detection signal based at least in part on the sensing signal; and a mode detector configured to: receive the sensing signal; and generate the mode detection signal based at last in part on the sensing signal.
27. The system of claim 26 wherein the voltage detector includes a voltage divider including a first resistor and a second resistor.
28. A system for controlling one or more light emitting diodes, the system comprising: a modified signal generator configured to receive a phase detection signal associated with a rectified voltage and a mode detection signal associated a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold, the modified signal generator being further configured to generate, based at least in part on the phase detection signal and the mode detection signal, a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; wherein: the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; the fourth time duration is smaller than the second time duration in magnitude; and the third time duration and the fourth time duration are equal in magnitude.
29. A method for controlling one or more light emitting diodes, the method comprising: receiving a phase detection signal associated with a rectified voltage and a mode detection signal associated a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the phase detection signal representing a first time duration during which the first waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; modifying the phase detection signal based at least in part on the mode detection signal; generating a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; receiving the modified signal; and controlling, based at least in part of the modified signal, a first current flowing through the one or more light emitting diodes configured to receive the rectified voltage; wherein: the first time duration and the second time duration are different in magnitude; and the third time duration and the fourth time duration are the same in magnitude.
30. A method for controlling one or more light emitting diodes, the method comprising: receiving a phase detection signal associated with a rectified voltage and a mode detection signal associated a TRIAC dimmer, the rectified voltage corresponding to a first waveform during a first half cycle of an AC voltage and corresponding to a second waveform during a second half cycle of the AC voltage, the phase detection signal representing a first time duration during which the first

waveform indicates that the rectified voltage is larger than a predetermined threshold and representing a second time duration during which the second waveform indicates that the rectified voltage is larger than the predetermined threshold; and generating, based at least in part on the phase detection signal and the mode detection signal, a modified signal representing a third time duration corresponding to the first half cycle of the AC voltage and a fourth time duration corresponding to the second half cycle of the AC voltage; wherein: the first time duration is smaller than the second time duration in magnitude; the third time duration is equal to the first time duration in magnitude; the fourth time duration is smaller than the second time duration in magnitude; and the third time duration and the fourth time duration are equal in magnitude.