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(54) Title: FLUORESCENT LAMP INFORMATION DETECTION SYSTEM AND METHOD

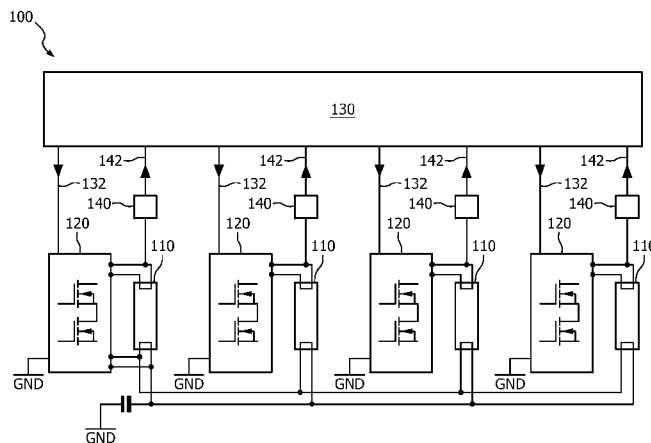
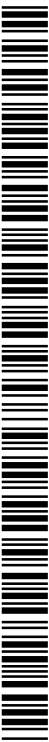


FIG. 1

(57) Abstract: A fluorescent lamp information detection system and method including an information detection system for fluorescent lamps, the system including inverters (120), each of the inverters (120) being operably connected across the high end filament of one of the fluorescent lamps; a controller (130) responsive to a lamp information signal (142) to determine a lamp condition of each of the fluorescent lamps; and lamp information detection circuits (140). Each of the lamp information detection circuits (140) includes a series resistance circuit operably connected between a DC voltage and ground, the series resistance circuit operably connecting in series a first resistance, the high end filament, a second resistance, and a third resistance; a capacitance operably connected in parallel with the third resistance; and a voltage tap operably connected between the second resistance and the third resistance, the voltage tap providing the lamp information signal (142).



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FLUORESCENT LAMP INFORMATION DETECTION SYSTEM AND METHOD

5 The technical field of this disclosure is lamp power supplies, particularly, a fluorescent lamp information detection system and method.

10 Electronic ballasts can be used to provide high frequency AC power to light fluorescent lamps. Electronic ballasts commonly perform a number of power-related functions including, inter alia, the conversion of power from the primary sources to AC voltages and frequencies corresponding to the requirements of respective lamps, and the limiting and control of the flow of electrical current to the lamps.

15 Fluorescent lamps in multi-lamp fixtures can be installed in different configurations to accomplish different purposes. In one configuration, the fluorescent lamps are connected in parallel and each lamp has a dedicated inverter to power the lamp. This configuration allows independent lamp operation, but requires that the electronic ballast controlling all the lamps be provided with information about each lamp. The electronic ballast needs to detect lamp information, such as lamp removal, lamp insertion, lamp de-gased, lamp end-of-life, and/or through pin leakage, so that the electronic ballast can start up or shut down the inverter for each lamp as required.

20 Electronic ballasts presently employ a separate circuit for each piece of information for each inverter. For an electronic ballast limiting signal detection to three conditions, such as lamp insertion, lamp de-gased, and lamp end-of-life, three separate circuits are required for each inverter. In a four lamp fixture with one inverter per lamp, the number of signals increases to twelve: one for each of the three conditions per inverter times four inverters. Unfortunately, this large number of circuits and signals increases complexity, manufacturing expense and price of purchase, while reducing reliability.

25 It would be desirable to have a fluorescent lamp information detection system and method that would overcome the above disadvantages.

30 One aspect of the present invention provides an information detection system for fluorescent lamps operably connected in parallel, each of the fluorescent lamps having a high end filament and a low end filament, the system including inverters, each of the inverters being operably connected across the high end filament of one of the fluorescent lamps, and at least one of the inverters being operably connected across the low end filaments of the fluorescent lamps; a controller responsive to a lamp information signal to determine a lamp

condition of each of the fluorescent lamps; and lamp information detection circuits. Each of the lamp information detection circuits includes a series resistance circuit operably connected between a DC voltage and ground, the series resistance circuit operably connecting in series a first resistance, the high end filament, a second resistance, and a third resistance; a
5 capacitance operably connected in parallel with the third resistance; and a voltage tap operably connected between the second resistance and the third resistance, the voltage tap providing the lamp information signal.

Another aspect of the present invention provides an information detection system for fluorescent lamps operably connected in parallel, each of the fluorescent lamps having a high
10 end filament and a low end filament, the system including inverters, each of the inverters being operably connected across the high end filament, and at least one of the inverters being operably connected across the low end filaments of the fluorescent lamps; a controller responsive to a lamp information signal to determine a lamp condition of each of the fluorescent lamps; and lamp information detection circuits, each of the lamp information
15 detection circuits providing the lamp information signal for one of the fluorescent lamps to the controller. The controller is operable to determine the lamp conditions of lamp insertion and lamp end-of-life in response to the lamp information signals.

Another aspect of the present invention provides an information detection method for fluorescent lamps operably connected in parallel, each of the fluorescent lamps having a high
20 end filament and a low end filament, the method including operably connecting an inverter across the high end filament of each of the fluorescent lamps and at least one of the inverters across the low end filaments of the fluorescent lamps; monitoring the high end filament of each of the fluorescent lamps to determine a lamp information signal for each of the fluorescent lamps; and determining a lamp condition for each of the fluorescent lamps in
25 response to the lamp information signal for each of the fluorescent lamps. The determining a lamp condition is operable to determine the lamp conditions of lamp insertion and lamp end-of-life.

The foregoing and other features and advantages of the invention will become further apparent from the following detailed description of the presently preferred embodiments,
30 read in conjunction with the accompanying drawings. The detailed description and drawings

are merely illustrative of the invention, rather than limiting the scope of the invention being defined by the appended claims and equivalents thereof.

FIG. 1 is a block diagram of a multi-lamp configuration with a fluorescent lamp information detection system in accordance with the present invention.

5 **FIG. 2** is a schematic diagram of a two lamp configuration with a fluorescent lamp information detection system in accordance with the present invention.

FIG. 3 is a schematic diagram of a four lamp configuration with a fluorescent lamp information detection system in accordance with the present invention.

10 **FIG. 4** is a schematic diagram of an equivalent circuit of a lamp insertion detection circuit for a fluorescent lamp information detection system in accordance with the present invention.

FIG. 5 is a schematic diagram of an equivalent circuit of an end-of-life detection circuit for a fluorescent lamp information detection system in accordance with the present invention.

15 **FIG. 6** is a schematic diagram of an equivalent circuit of a through pin leakage detection circuit for a fluorescent lamp information detection system in accordance with the present invention.

FIGS. 7A-7E are graphical representations of lamp information signals for a fluorescent lamp information detection system in accordance with the present invention.

20 **FIG. 8** is a flowchart of a fluorescent lamp information detection method in accordance with the present invention.

FIG. 1 is a block diagram of a multi-lamp configuration with a fluorescent lamp information detection system in accordance with the present invention.

25 The multi-lamp configuration **100** includes a number of fluorescent lamps **110** operably connected in parallel, with one inverter **120** operably connected to each lamp **110**. A lamp information detection circuit **140** is operably connected to each of the lamps **110** to detect lamp condition, such as lamp insertion, lamp end-of-life, through pin leakage, lamp de-gased, lamp removal, and the like, and to generate a lamp information signal **142** in response
30 to the lamp condition. A controller **130** receives the lamp information signals **142** from each of the lamp information detection circuit **140** and provides inverter control signals **132** to

each of the inverters **120** in response to the individual lamp information signal **142**. The controller **130** is operable to start up or shut down the each of the inverters **120** and its associated lamp **110** through the inverter control signals **132**. Those skilled in the art will appreciate that the controller **130** can be any analog or digital voltage detection circuit, such as a microcontroller, microprocessor, digital signal processor, or the like, operable to receive a number of lamp information signals **142** and generate a number of inverter control signals **132**.

FIG. 2, in which like elements share like reference numbers with **FIG. 1**, is a schematic diagram of a two lamp configuration with a fluorescent lamp information detection system in accordance with the present invention. In this example, two fluorescent lamps are operably connected in parallel with one inverter for each of the fluorescent lamps. Only Two lamp information signals, one for each lamp, are required to determine the lamp condition of each of the fluorescent lamps.

The information detection system **200** includes inverters **220, 260**, a controller **130**, and lamp information detection circuits **240, 280**. The information detection system **200** obtains information from the fluorescent lamps **210, 250**, which are operably connected in parallel. The lamps **210, 250** each have a high end filament **212, 252** and a low end filament **214, 254**. The low end filaments **214, 254** are operably connected in parallel. Each of the inverters **220, 260** is operably connected across the high end filament **212, 252** of one of the lamps **210, 250**, and one of the inverters **220** is operably connected across the low end filaments **214, 254** of the fluorescent lamps **210, 250**. In this example, the inverter **220** provides power to both of the low end filaments **214, 254**. In another example (not shown), one inverter can provide power to one low end filament and the other inverter can provide power to the other low end filament. The inverters **220, 260** are connected to ground.

The controller **130** is responsive to lamp information signals **242, 282** from the lamp information detection circuits **240, 280** to determine the lamp condition of each of the lamps **210, 250**. The controller **130** can generate inverter control signals (not shown) for each of the inverters **220, 260** in response to the individual lamp information signals **242, 282**. The information detection system **200** can also include a common parallel circuit **290** with common resistance R13 and common capacitance C5 operably connected in parallel. The common parallel circuit **290** is operably connected between the low end filaments **214, 254**

for all of the lamps **210**, **250** and ground GND. The common parallel circuit **290** provides wire short protection in case of miswiring, providing a short to earth ground. The common resistance R13 allows DC to pass and the common capacitance C5 breaks any current loop by increasing impedance with decreasing frequency.

5 The lamp information detection circuit **240** includes a series resistance circuit of a string of resistors operably connected between DC voltage V_{DC} and ground GND. The series resistance circuit operably connects in series a first resistance R1, the high end filament **212**, a second resistance R2, and a third resistance R3. A capacitance C1 is operably connected in parallel with the third resistance R3. A voltage tap **244** is operably connected between the
10 second resistance R2 and the third resistance R3 to provide the lamp information signal **242**.

 The lamp information detection circuit **280** includes a series resistance circuit operably connected between DC voltage V_{DC} and ground GND. The series resistance circuit operably connects in series a first resistance R4, the high end filament **252**, a second resistance R5, and a third resistance R6. A capacitance C2 is operably connected in parallel
15 with the third resistance R6. A voltage tap **284** is operably connected between the second resistance R5 and the third resistance R6 to provide the lamp information signal **282**.

 In one embodiment for a four lamp configuration with a fluorescent lamp type T5HO 54W, the DC voltage V_{DC} is 150 Volts, first resistance R1 is 1.41 MOhms, second resistance R2 is 900 KOhms, third resistance R3 is 68 KOhms, and capacitance C1 is 0.1 microfarads.
20 Parallel components associated with parallel lamps (e.g., first resistance R4, second resistance R5, third resistance R6, and capacitance C2) have the same component values. The common resistance R13 is 300 KOhms and the common capacitance C5 is 0.47 microfarads in the common parallel circuit **290**. Those skilled in the art will appreciate that the component values can be selected as desired for a particular application.

25 **FIG. 3**, in which like elements share like reference numbers with **FIG. 1**, is a schematic diagram of a four lamp configuration with a fluorescent lamp information detection system in accordance with the present invention. In this example, four fluorescent lamps are operably connected in parallel. Only four lamp information signals, one for each lamp, are required to determine the lamp condition of each of the fluorescent lamps. Those
30 skilled in the art will appreciate that the fluorescent lamp information detection system can be used with any number of fluorescent lamps as desired for a particular application.

The fluorescent lamp information detection system can be used to determine lamp conditions for fluorescent lamps operably connected in parallel, such as lamp insertion, lamp end-of-life, through pin leakage, lamp de-gased, lamp removal, and combinations thereof. All the lamp conditions for a single lamp can be provided to the controller on a single lamp information signal.

The lamp information detection circuit can detect when a lamp is inserted into or removed from a lamp fixture, the lamp condition of lamp insertion. When no lamp is present in the lamp fixture, the circuit between DC voltage V_{DC} and ground GND is open between first resistance R1 and second resistance R2, so the voltage of the lamp information signal V_{Lamp1} at the voltage tap between the second resistance R2 and the third resistance R3 is zero. When a lamp is inserted, the lamp filament completes the circuit between DC voltage V_{DC} and ground GND through the first resistance R1, second resistance R2, and third resistance R3. Before the newly inserted lamp is ignited, the lamp information signal V_{Lamp1} at the voltage tap is:

$$V_{lamp1_insertion} = \frac{R3}{R1 + R2 + R3} \cdot V_{dc}$$

The controller determines that a lamp is inserted when the lamp information signal V_{Lamp1} increases from zero Volts to lamp insertion voltage $V_{Lamp1_insertion}$.

FIG. 4 is a schematic diagram of an equivalent circuit of a lamp insertion detection circuit for a fluorescent lamp information detection system in accordance with the present invention. The equivalent circuit is for an ignited lamp which conducts. For the example of a T5 HO (High Output) lamp, the lamp voltage is 118 Volts, the lamp current is 0.46 Amps, and the lamp resistance R_L is 256 Ohms, which is small compared to other resistances in the equivalent circuit. The lamp information signal V_{Lamp1} decreases from lamp insertion voltage $V_{Lamp1_insertion}$ to lamp running voltage $V_{Lamp1_running}$ when the lamp ignites.

The lamp running voltage $V_{Lamp1_running}$ can be calculated from the equivalent circuit of **FIG. 4**. The other lamp current I_{other} is the sum of the DC currents received from other lamps operably connected in parallel with the first lamp (Lamp1). When there are four lamps operably connected in parallel, ignited, and the DC current through each lamp is individual lamp current I_{dc_lamp} , the other lamp current I_{other} is three times individual

lamp current I_{dc_lamp} . The voltage across common resistance $R13$ is four times individual lamp current I_{dc_lamp} times resistance $R13$, so the equivalent resistance of common resistance $R13$ is four times resistance $R13$. For the general case in which N lamps are ON, the equivalent resistance of common resistance $R13$ is N times resistance $R13$.

5 Disregarding the lamp resistance R_L as negligible, the lamp running voltage $V_{Lamp1_running}$ is:

$$V_{lamp1_running} = V_{dc} \cdot \frac{1}{\frac{N \cdot R13 \cdot (R2 + R3)}{N \cdot R13 + R2 + R3} + R1} \cdot \frac{N \cdot R13}{R2 + R3 + N \cdot R13} \cdot R3$$

10

The lamp running voltage $V_{Lamp1_running}$ is usually much lower than lamp insertion voltage $V_{Lamp1_insertion}$ and depends on the number of lamps that are ON. The controller determines that a lamp is ignited when the lamp information signal V_{Lamp1} decreases from lamp insertion voltage $V_{Lamp1_insertion}$ to lamp running voltage $V_{Lamp1_running}$.

15

Those skilled in the art will appreciate that for most applications the decrease in voltage will be sufficient to determine that a lamp has ignited and is running, regardless of the number of other lamps that are ON.

20

The lamp information detection circuit can also detect when a lamp is removed from the lamp fixture, the lamp condition of lamp removal. When a lamp is ON, the lamp information signal V_{Lamp1} is lamp running voltage $V_{Lamp1_running}$. When a lamp is removed, the lamp information signal V_{Lamp1} decreases to zero Volts. The controller determines that a lamp is removed when the lamp information signal V_{Lamp1} decreases from lamp running voltage $V_{Lamp1_running}$ to zero Volts. The controller can then provide an inverter control signal to shut down the inverter for the removed lamp while the other lamps remain operating.

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The lamp information detection circuit can also detect when a lamp is de-gased, i.e., when the lamp fill gas has leaked out due to cracks in the lamp tube, seal leakage, or the like, the lamp condition of lamp de-gased. The lamp filament can be intact, but the lamp can no longer ignite, so the lamp resistance is infinite. The equivalent circuit is same as when a lamp is inserted, but before the lamp is ignited. The lamp de-gased voltage $V_{Lamp1_de-gased}$ is equal to the lamp insertion voltage $V_{Lamp1_insertion}$, which is usually much higher than the lamp running voltage $V_{Lamp1_running}$. The controller determines that a

lamp is de-gased when the lamp information signal V_Lamp1 increases from lamp running voltage $V_Lamp1_running$ to lamp insertion voltage $V_Lamp1_insertion$. The controller can then provide an inverter control signal to shut down the inverter for the de-gased lamp while the other lamps remain operating.

5 **FIG. 5** is a schematic diagram of an equivalent circuit of an end-of-life detection circuit for a fluorescent lamp information detection system in accordance with the present invention. The lamp information detection circuit can detect when a lamp is at the end-of-life (EOL), the lamp condition of lamp EOL. At EOL, the lamp can act as a rectifier. Lamp current is pure alternating current because a DC blocking capacitor is installed in series with the lamp. The equivalent circuit for the lamp can be expressed as a lamp resistance R_L in series with a DC EOL voltage V_{EOL} , which is the DC voltage in the lamp when the lamp reaches end-of-life.

10 The lamp EOL voltage V_Lamp1_EOL is equal to the lamp running voltage $V_Lamp1_running$ plus or minus the quantity of a resistor divider constant K times DC EOL voltage V_{EOL} . The resistor divider constant K is determined by the value of all the resistors in the circuit. The controller determines that a lamp is at EOL when the lamp information signal V_Lamp1 increases or decreases from lamp running voltage $V_Lamp1_running$ to fall outside of an allowable lamp EOL window. The lamp running voltage $V_Lamp1_running$ varies with the number of lamps which are ON, so the center point about which the quantity of a resistor divider constant K times DC EOL voltage V_{EOL} changes varies as well. The component values in the circuit are selected to indicate EOL without a large change indicating another lamp condition, such as lamp de-gased or lamp removal. Those skilled in the art will appreciate that the component values for the DC voltage V_{DC} and resistors R_1 , R_2 , R_3 , and R_{13} can be selected as desired for a particular application and for the particular lamps. The controller determines that a lamp is at lamp EOL when the lamp information signal V_Lamp1 is outside of an allowable lamp EOL window plus or minus a lamp EOL voltage limit centered on the lamp running voltage. In one example, the allowable lamp EOL window is about 1 Volt wide. The controller can then provide an inverter control signal to shut down the inverter for the EOL lamp while the other lamps remain operating.

25 30 **FIG. 6** is a schematic diagram of an equivalent circuit of a through pin leakage detection circuit for a fluorescent lamp information detection system in accordance with the

present invention. The lamp information detection circuit can detect when a lamp exhibits the lamp condition of through pin leakage, which can occur when the high end of the lamp is connected in the lamp fixture and the low end of the lamp is grounded through a small resistance, such as 500 Ohms, as specified in UL Standard 935, Standard for Fluorescent-Lamp Ballasts, regarding lamp leakage current measurement. There is no isolation between the lamp and the main circuit, so the lamp ignites and lamp current flows to ground through the small resistance and input bridge diode. This circuit path couples a rectified input line voltage $V_{\text{rect_line}}$, such as a 60 Hz voltage, into the lamp voltage.

Referring to **FIG. 2**, the values of capacitor C1 and third resistance R3 are selected to pass the rectified input line voltage, such as a 60 Hz voltage, on the lamp information signal V_{Lamp1} . The controller determines that a lamp exhibits through pin leakage when the lamp information signal V_{Lamp1} includes an input line frequency f_{line} with a voltage amplitude above an input line voltage limit $V_{\text{line_pinleak_lim}}$. In one example, the controller determines that a lamp exhibits through pin leakage when the controller detects an input line frequency f_{line} of 60 Hz with a voltage amplitude above an input line voltage limit $V_{\text{line_pinleak_lim}}$ of 2.0 Volts at the controller pin. The controller can then provide an inverter control signal to shut down the inverter for the lamp exhibiting through pin leakage while the other lamps remain operating.

FIGS. 7A-7E are graphical representations of lamp information signals for a fluorescent lamp information detection system in accordance with the present invention. The controller determines the lamp condition of each of the fluorescent lamps by monitoring the of lamp information signal for each of the fluorescent lamps. The graphical representations are exemplary only and are not to scale.

FIG. 7A is a hypothetical voltage trace of a lamp information signal V_{Lamp1} from which the controller can determine the lamp conditions of lamp insertion and lamp ignition. During time period T0, the lamp is not installed in the lamp fixture, so the lamp information signal V_{Lamp1} is zero. At time T1, the lamp is installed in the lamp fixture and the lamp information signal V_{Lamp1} increases in voltage to lamp insertion voltage $V_{\text{Lamp1_insertion}}$. The controller determines the lamp condition as being lamp insertion from the increase in voltage. During time period T2, the lamp remains off and is igniting, so the lamp information signal V_{Lamp1} remains at lamp insertion voltage $V_{\text{Lamp1_insertion}}$.

At time T3, the lamp ignites at the lamp information signal V_Lamp1 decreases from lamp insertion voltage V_Lamp1_insertion to lamp running voltage V_Lamp1_running, which is greater than zero. The controller determines the lamp condition as being lamp running from the decrease in voltage.

5 **FIG. 7B** is a hypothetical voltage trace of a lamp information signal V_Lamp1 from which the controller can determine the lamp condition of lamp removal. During time period T0, the lamp is running and the lamp information signal V_Lamp1 is lamp running voltage V_Lamp1_running. At time T1, the lamp is removed from the lamp fixture and the lamp information signal V_Lamp1 decreases to zero. The controller determines the lamp condition
10 as being lamp removal from the decrease in voltage. During time period T2, the lamp remains removed, so the lamp information signal V_Lamp1 remains at zero.

FIG. 7C is a hypothetical voltage trace of a lamp information signal V_Lamp1 from which the controller can determine the lamp condition of lamp end-of-life (EOL). During time period T0, the lamp is running and the lamp information signal V_Lamp1 is lamp running voltage V_Lamp1_running. At time T1, the lamp reaches EOL and the lamp information signal V_Lamp1 falls outside of the allowable lamp EOL window between plus or minus a lamp EOL voltage limit V_lamp_EOL_lim centered on the lamp running voltage V_Lamp1_running. In this example, the lamp information signal V_Lamp1 increases to pass
15 through the plus lamp EOL voltage limit V_lamp_EOL_lim above the lamp running voltage V_Lamp1_running. In another example of indication a lamp condition of EOL (not shown), the lamp information signal V_Lamp1 decreases to pass through the minus lamp EOL voltage limit V_lamp_EOL_lim below the lamp running voltage V_Lamp1_running. Those skilled in the art will appreciate that the lamp can reach EOL over a long time, rather than the abrupt change at time T1 provided in this example. The controller determines the lamp
20 condition as being lamp EOL from the change in the voltage to a value outside the allowable lamp EOL window. During time period T2, the lamp remains beyond EOL, so the lamp information signal V_Lamp1 remains outside the allowable lamp EOL window.

30 **FIG. 7D** is a hypothetical voltage trace of a lamp information signal V_Lamp1 from which the controller can determine the lamp condition of through pin leakage. During time

period T0, the lamp is running and the lamp information signal V_Lamp1 is lamp running voltage V_Lamp1_running. At time T1, the low end of the lamp, i.e., the end of the lamp with the low end filament, is removed from the lamp fixture and grounded through a small resistance. The lamp information signal V_Lamp1 then includes an input line frequency f_line with a voltage amplitude above an input line voltage limit V_line_pinleak_lim. The controller determines the lamp condition as being through pin leakage from the presence in the lamp information signal V_Lamp1 of the input line frequency f_line with a voltage amplitude above an input line voltage limit V_line_pinleak_lim. During time period T2, the through pin leakage remains, so the lamp information signal V_Lamp1 continues to include the input line voltage f_line with a voltage amplitude above an input line voltage limit V_line_pinleak_lim. Those skilled in the art will appreciate that the lamp can start from lamp conditions other than lamp running when the through pin leakage occurs, so that the initial value of the lamp information signal V_Lamp1 can be different than the lamp running voltage V_Lamp1_running.

FIG. 7E is a hypothetical voltage trace of a lamp information signal V_Lamp1 from which the controller can determine the lamp condition of lamp de-gased. During time period T0, the lamp is running and the lamp information signal V_Lamp1 is lamp running voltage V_Lamp1_running. At time T1, the lamp becomes de-gased and the lamp information signal V_Lamp1 increases to lamp de-gased voltage V_Lamp1_de-gased, which is equal to the lamp insertion voltage V_Lamp1_insertion. The controller determines the lamp condition as being lamp de-gased from the increase in voltage. During time period T2, the lamp remains de-gased, so the lamp information signal V_Lamp1 remains at lamp de-gased voltage V_Lamp1_de-gased.

FIG. 8 is a flowchart of a fluorescent lamp information detection method in accordance with the present invention. The information detection method can be used for fluorescent lamps operably connected in parallel, with each of the fluorescent lamps having a high end filament and a low end filament. The method **700** includes operably connecting an inverter across the high end filament of each of the fluorescent lamps and at least one of the inverters across the low end filaments of the fluorescent lamps **710**; monitoring the high end filament of each of the fluorescent lamps to determine a lamp information signal for each of the fluorescent lamps **720**; and determining a lamp condition for each of the fluorescent

lamps in response to the lamp information signal for each of the fluorescent lamps **730**. The determining a lamp condition is operable to determine both lamp conditions of lamp insertion and lamp end-of-life.

5 The determining a lamp condition **730** can include determining the lamp condition of lamp insertion from an increase in the lamp information signal from zero to lamp insertion voltage; and determining the lamp condition of lamp end-of-life (EOL) from a change in the lamp information signal from lamp running voltage to a voltage outside of an allowable lamp EOL window between plus or minus a lamp EOL voltage limit centered on the lamp running voltage.

10 The determining a lamp condition **730** can also include determining the lamp condition of through pin leakage from presence in the lamp information signal of an input line frequency with a voltage amplitude above an input line voltage limit; determining the lamp condition of lamp de-gased from an increase in the lamp information signal from lamp running voltage to lamp de-gased voltage; and determining the lamp condition of lamp
15 removal from a decrease in the lamp information signal from lamp running voltage to zero.

While the embodiments of the invention disclosed herein are presently considered to be preferred, various changes and modifications can be made without departing from the scope of the invention. The scope of the invention is indicated in the appended claims, and all changes that come within the meaning and range of equivalents are intended to be
20 embraced therein.

CLAIMS

1. An information detection system for fluorescent lamps operably connected in parallel, each of the fluorescent lamps having a high end filament and a low end filament, the system
5 comprising:

inverters **(120)**, each of the inverters **(120)** being operably connected across the high end filament of one of the fluorescent lamps, and at least one of the inverters **(120)** being operably connected across the low end filaments of the fluorescent lamps;

10 a controller **(130)** responsive to a lamp information signal **(142)** to determine a lamp condition of each of the fluorescent lamps; and

lamp information detection circuits **(140)**, each of the lamp information detection circuits **(140)** comprising:

15 a series resistance circuit operably connected between a DC voltage and ground, the series resistance circuit operably connecting in series a first resistance, the high end filament, a second resistance, and a third resistance;

a capacitance operably connected in parallel with the third resistance; and

20 a voltage tap operably connected between the second resistance and the third resistance, the voltage tap providing the lamp information signal **(142)**.

2. The information detection system of claim 1 wherein the controller **(130)** is operable to determine a lamp condition selected from the group consisting of lamp insertion, lamp end-of-life, through pin leakage, lamp de-gased, and lamp removal.

3. The information detection system of claim 3 wherein the controller **(130)** is further
25 operable to provide an inverter control signal **(132)** to one of the inverters **(120)** to shut down the inverter **(120)** for one of the fluorescent lamps having the lamp condition selected from the group consisting of lamp end-of-life, through pin leakage, lamp de-gased, and lamp removal.

4. The information detection system of claim 1 further comprising a common resistance and a common capacitance operably connected in parallel between the low end filaments of all of the fluorescent lamps and ground.
5. The information detection system of claim 1 wherein the controller **(130)** is operable to determine the lamp condition of lamp insertion from an increase in the lamp information signal **(142)** from zero to lamp insertion voltage.
6. The information detection system of claim 5 wherein the controller **(130)** is further operable to determine the lamp condition of lamp running from a decrease in the lamp information signal **(142)** from the lamp insertion voltage to lamp running voltage.
7. The information detection system of claim 1 wherein the controller **(130)** is operable to determine the lamp condition of lamp end-of-life (EOL) from a change in the lamp information signal **(142)** from lamp running voltage to a voltage outside of an allowable lamp EOL window between plus or minus a lamp EOL voltage limit centered on the lamp running voltage.
8. The information detection system of claim 1 wherein the controller **(130)** is operable to determine the lamp condition of through pin leakage from presence in the lamp information signal **(142)** of an input line frequency with a voltage amplitude above an input line voltage limit.
9. The information detection system of claim 1 wherein the controller **(130)** is operable to determine the lamp condition of lamp de-gassed from an increase in the lamp information signal **(142)** from lamp running voltage to lamp degassed voltage.
10. The information detection system of claim 1 wherein the controller **(130)** is operable to determine the lamp condition of lamp removal from a decrease in the lamp information signal **(142)** from lamp running voltage to zero.

11. An information detection system for fluorescent lamps operably connected in parallel, each of the fluorescent lamps having a high end filament and a low end filament, the system comprising:

inverters (120), each of the inverters (120) being operably connected across the high end filament of one of the fluorescent lamps, and at least one of the inverters (120) being operably connected across the low end filaments of the fluorescent lamps;

a controller (130) responsive to a lamp information signal (142) to determine a lamp condition of each of the fluorescent lamps; and

lamp information detection circuits (140), each of the lamp information detection circuits (140) providing the lamp information signal (142) for one of the fluorescent lamps to the controller (130);

wherein the controller (130) is operable to determine the lamp conditions of lamp insertion and lamp end-of-life in response to the lamp information signals (142).

12. The information detection system of claim 11 wherein the controller (130) is further operable to determine a lamp condition selected from the group consisting of through pin leakage, lamp de-gased, and lamp removal.

13. The information detection system of claim 11 further comprising a common resistance and a common capacitance operably connected in parallel between the low end filaments of all of the fluorescent lamps and ground.

14. The information detection system of claim 11 wherein:

the controller (130) is operable to determine the lamp condition of lamp insertion from an increase in the lamp information signal (142) from zero to lamp insertion voltage; and

the controller (130) is operable to determine the lamp condition of lamp end-of-life (EOL) from a change in the lamp information signal (142) from lamp running voltage to a voltage outside of an allowable lamp EOL window between plus or minus a lamp EOL voltage limit centered on the lamp running voltage.

15. The information detection system of claim 11 wherein the controller **(130)** is operable to determine the lamp condition of through pin leakage from presence in the lamp information signal **(142)** of an input line frequency with a voltage amplitude above an input line voltage limit.

5

16. The information detection system of claim 11 wherein the controller **(130)** is operable to determine the lamp condition of lamp de-gassed from an increase in the lamp information signal **(142)** from lamp running voltage to lamp degassed voltage.

10

17. The information detection system of claim 11 wherein the controller **(130)** is operable to determine the lamp condition of lamp removal from a decrease in the lamp information signal **(142)** from lamp running voltage to zero.

15

18. An information detection method for fluorescent lamps operably connected in parallel, each of the fluorescent lamps having a high end filament and a low end filament, the method comprising:

operably connecting an inverter across the high end filament of each of the fluorescent lamps and at least one of the inverters across the low end filaments of the fluorescent lamps **(710)**;

20

monitoring the high end filament of each of the fluorescent lamps to determine a lamp information signal for each of the fluorescent lamps **(720)**; and

determining a lamp condition for each of the fluorescent lamps in response to the lamp information signal for each of the fluorescent lamps **(730)**;

25

wherein the determining a lamp condition is operable to determine the lamp conditions of lamp insertion and lamp end-of-life.

19. The information detection method of claim 18 wherein the determining a lamp condition **(730)** comprises:

5 determining the lamp condition of lamp insertion from an increase in the lamp information signal from zero to lamp insertion voltage; and

determining the lamp condition of lamp end-of-life (EOL) from a change in the lamp information signal from lamp running voltage to a voltage outside of an allowable lamp EOL window between plus or minus a lamp EOL voltage limit centered on the lamp running voltage.

10

20. The information detection method of claim 18 wherein the determining a lamp condition **(730)** further comprises:

15 determining the lamp condition of through pin leakage from presence in the lamp information signal of an input line frequency with a voltage amplitude above an input line voltage limit;

determining the lamp condition of lamp de-gased from an increase in the lamp information signal from lamp running voltage to lamp de-gased voltage; and

determining the lamp condition of lamp removal from a decrease in the lamp information signal from lamp running voltage to zero.

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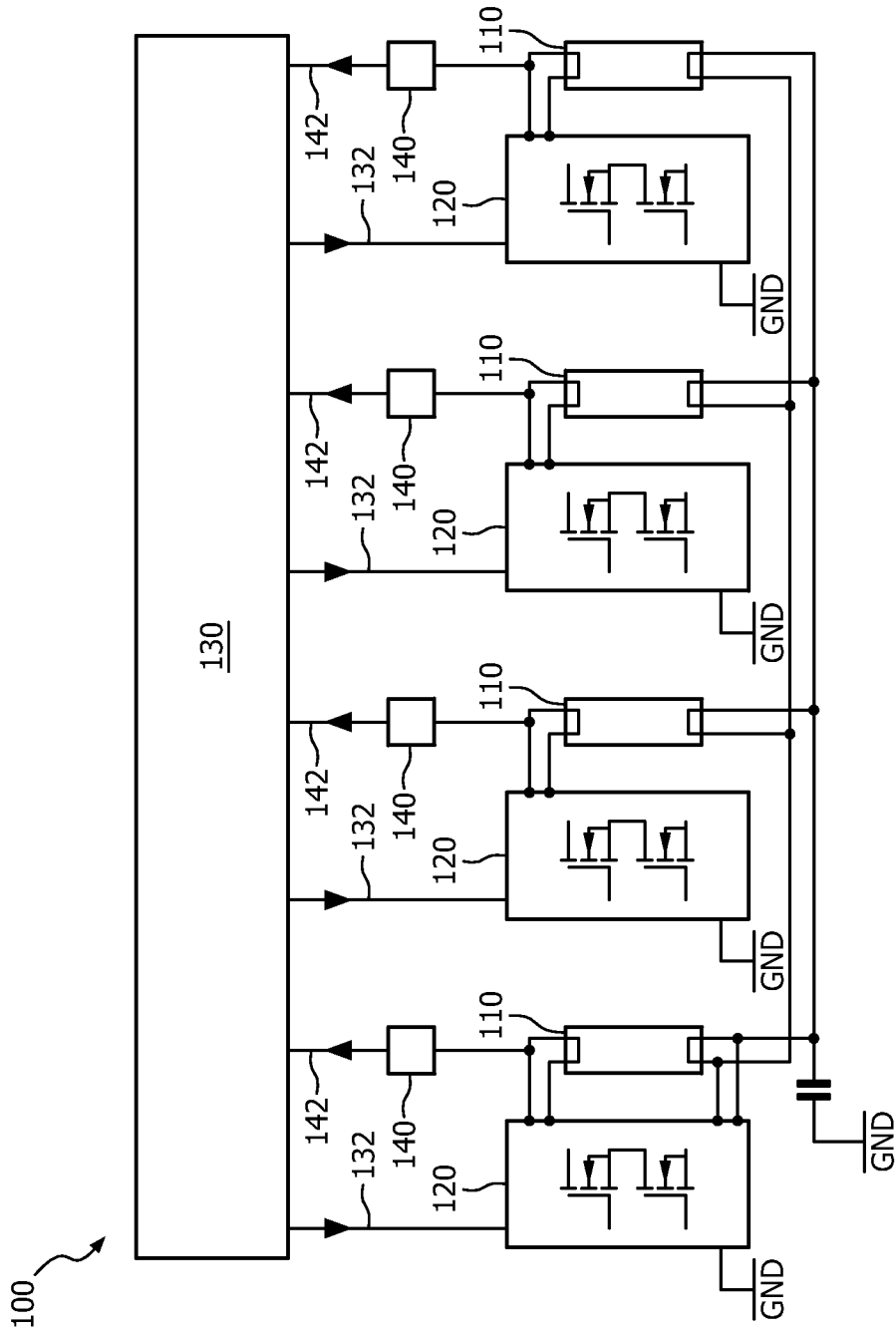


FIG. 1

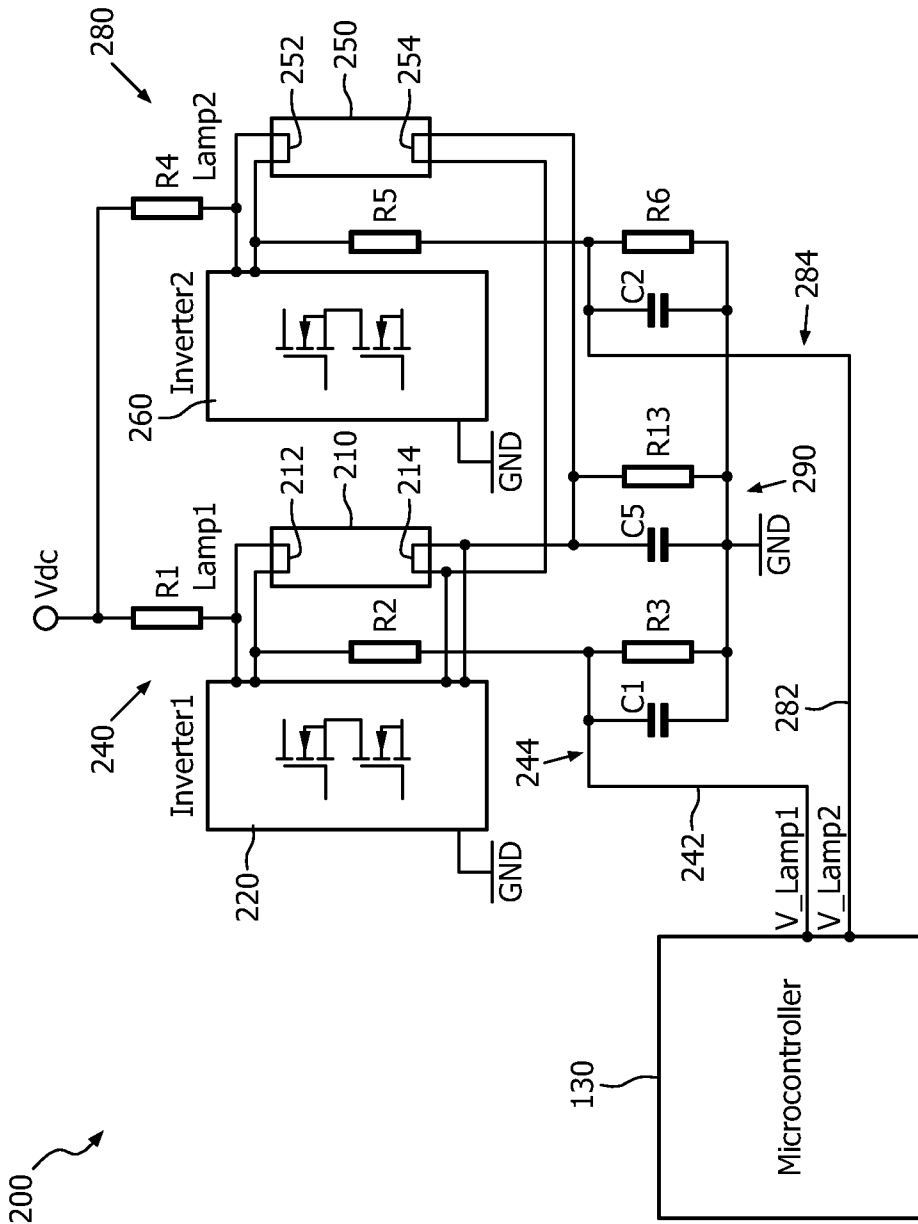


FIG. 2

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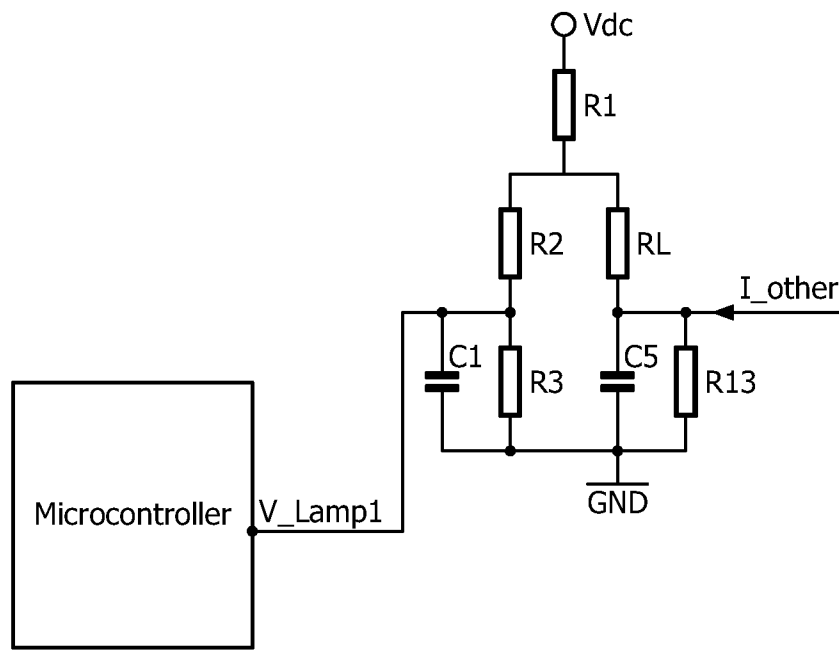


FIG. 4

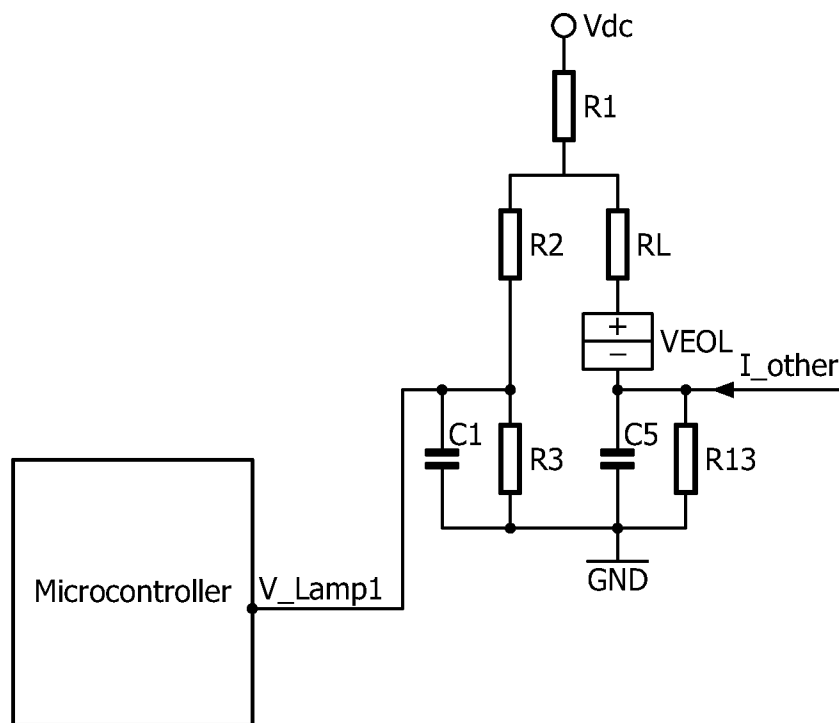


FIG. 5

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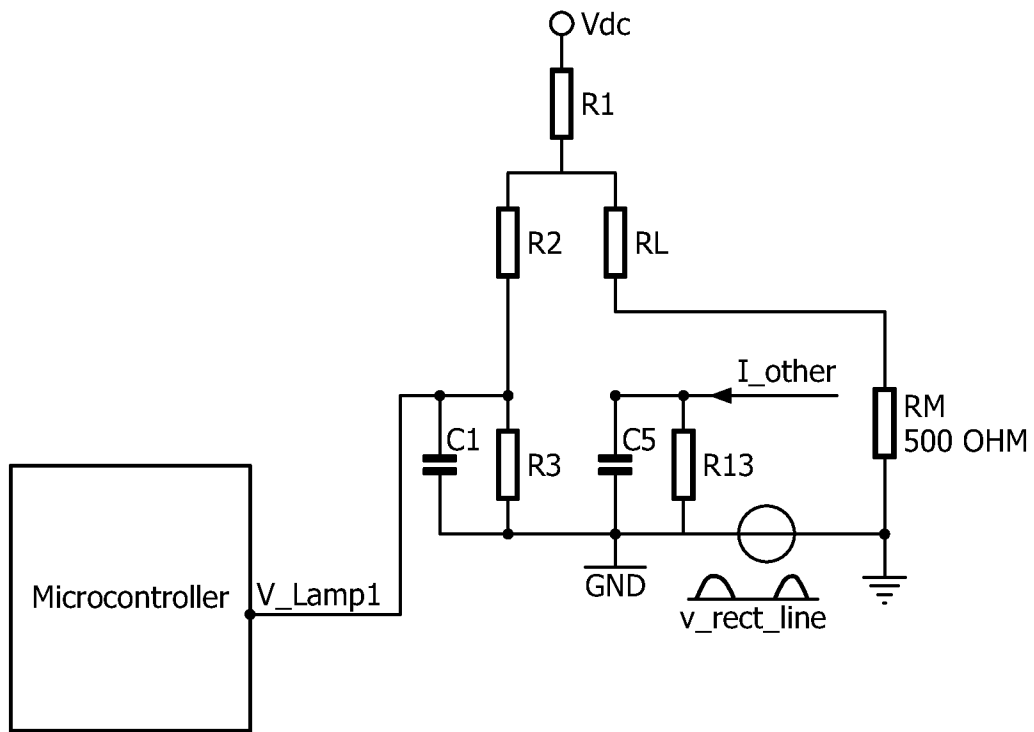


FIG. 6

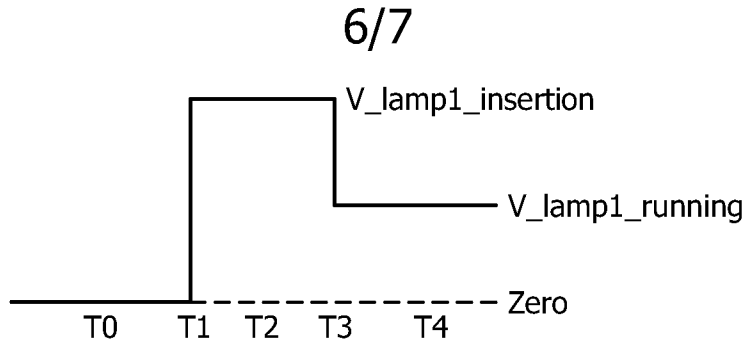


FIG. 7A

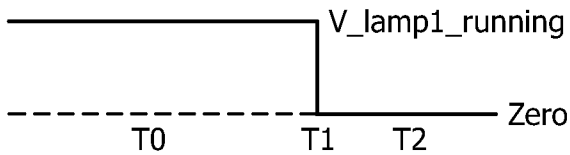


FIG. 7B

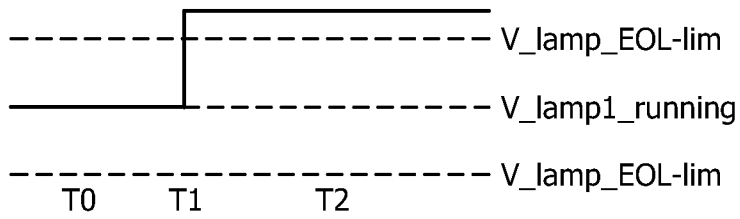


FIG. 7C

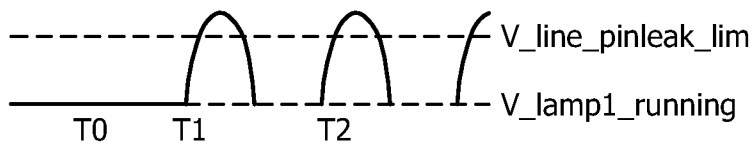


FIG. 7D



FIG. 7E

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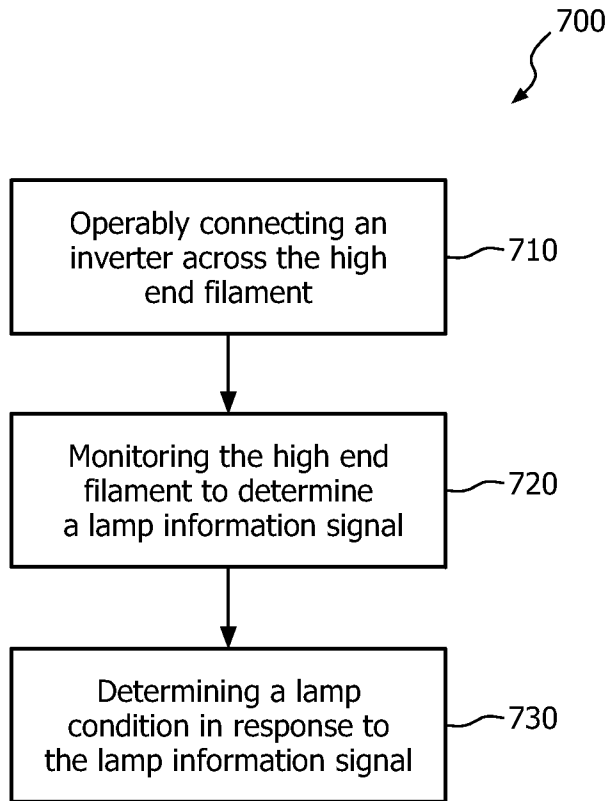


FIG. 8