(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 258 743 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
20.12.2017 Bulletin 2017/51

(51) Int Cl.:
H05B 33/08 *(2006.01)*

(21) Application number: **16174276.2**

(22) Date of filing: **13.06.2016**

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

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(54) **DIRECT DRIVE LED LIGHTING**

(57) A direct drive LED lighting circuit includes a LED current control circuit with a power switching device; a current sensing device, an averaging circuit, and an error amplifier. A LED chain circuit is formed by connecting several LEDs in series with a capacitor connecting in parallel with the series of LEDs, with a current flowing in side as a positive terminal, and a current leaving terminal as a negative terminal. The LED chain circuit and the LED current control circuit are connecting in series and the whole circuit is connected between the positive and negative terminals of a rectified AC power source.

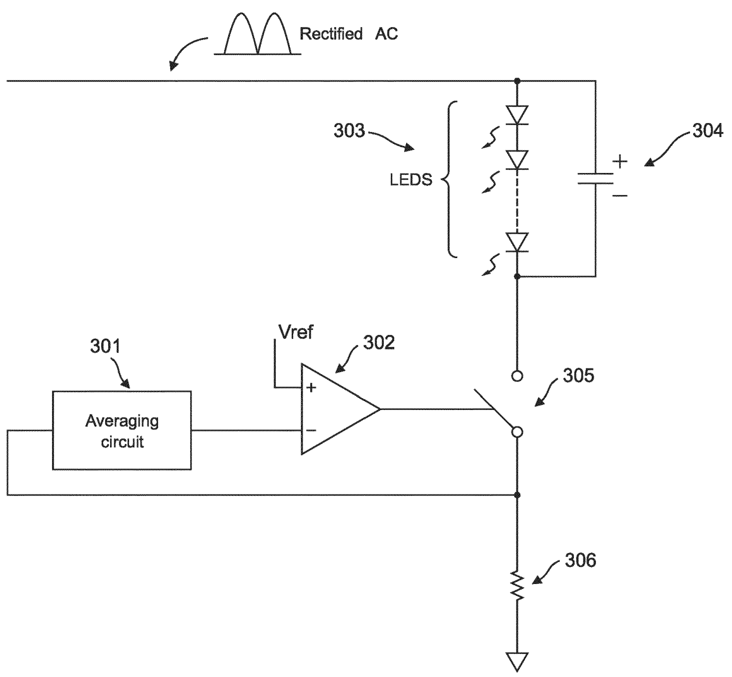

Fig. 3

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Description

Background of the Invention

[0001] The present invention relates to control circuits for LED lighting. The invention more particularly, although not exclusively, relates to driving LEDs in LED lighting products using direct drive architecture.

Prior Art

[0002] Prior art typical LED lighting direct drive circuit and the associated concept of LED voltage and current versus the AC cycle are illustrated in Figs. 1 and 2 respectively. While having the advantage of eliminating the magnetic component as compared with switching mode LED lighting driving circuits, direct drive LED lighting circuits today suffer from the following:

(a) Poor LED utilization due to some LEDs are not at full on state throughout the whole AC input cycle. As LED is the major cost in LED lighting product, this will increase the product cost.

(b) There exists a gap period between AC half cycles that all LEDs are off, as well as the changing of LED current and number of LED that are in on state with each AC half cycle, and hence changing the output brightness. These will create a relatively high flicker effect.

(c) To budget for the input AC voltage variation, the difference between the peak AC voltage and the maximum LED chain voltage is large. This creates substantial heat dissipation at the power switching device, and hence lowering the efficiency in such LED direct drive circuits. This will increase the packaging cost due to the package type selected needs to be able to handle such heat dissipation.

Objects of the Invention

[0003] It is an object of the present invention to overcome or substantially ameliorate some or all the above disadvantages and/or more generally to provide improved control circuits for direct drive LED lighting.

Disclosure of the Invention

[0004] There is disclosed herein a circuit including:

[0005] A direct drive LED lighting circuit comprising:

[0006] A LED current control circuit with a power switching device; a current sensing device, an averaging circuit, and an error amplifier; wherein

[0007] The power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and

[0008] A current sensing device for sensing the current flowing through the power switching device is connecting between the negative channel terminal of the power switching device and the reference node (lowest voltage) of the control circuit, the output of the current sensing device (or negative channel terminal of the power switching device for particular implementation) is connecting to the input of an averaging circuit; and

[0009] The averaging circuit with an input connected to the output of the current sensing device, and an output connected to one of the inputs of an error amplifier; and

[0010] The error amplifier with an output of the averaging circuit as one of the inputs, and reference voltage serving for setting of an average LED current as another input, and an output connected to the control terminal of the power switching device; and

[0011] A LED chain circuit by connecting several LEDs in series with a capacitor connecting in parallel with the series of LEDs, with a current flowing in terminal as a positive terminal, and a current leaving terminal as a negative terminal;

[0012] The LED chain circuit and the LED current control circuit are connecting in series and the whole circuit is connected between the positive and negative terminals of a rectified AC power source.

[0013] Optionally, a series diode to prevent the reverse current flow may be added either at the positive terminal or the negative terminal of the rectified AC power source, or between the LED chain circuit and the LED current control circuit.

[0014] Optionally, a filter circuit may be added between the error amplifier and the power switching device.

[0015] Preferably, the current sensing device can take the form of a simple resistor, or current mirror followed by current to voltage conversion, to produce a voltage representing the current flowing through the power switching device.

[0016] Preferably, the averaging circuit can take the form of passive low pass filter, or active low pass filter, or low pass filter with addition of sample and hold control for processing of the averaging function.

[0017] It is further disclosed herein a monolithic integrated circuit for direct drive LED light application comprising the following:

A power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and

An error amplifier with an output connected to the control terminal of the power switching device, an input connected to a reference voltage for setting the average current flowing through the power switching device, and another input for obtaining feedback information of the average current flowing through the power switching device.

Optionally, a filter circuit may be added between the error amplifier and the power switching device.

Preferably, an external current sensing device, averaging circuit, and LED chain circuit may be connected to produce intended application circuits.

It is further disclosed herein a direct drive LED lighting circuit comprising:

A LED current control circuit with a power switching device; a current sensing device, an averaging circuit, and a three input error amplifier; wherein

The power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and

A current sensing device for sensing the current flowing through the power switching device is connecting between the negative channel terminal of the power switching device and the reference node (lowest voltage) of the control circuit. The output of the current sensing circuit (or negative channel terminal of the power switching device for particular implementation) is also connecting to the input of an averaging circuit; and

The averaging circuit with an input connected to the output of the current sensing device, and an output connected to one of the inputs of a three input error amplifier; and

The three input error amplifier with the output of the averaging circuit as one of the inputs, and reference voltage serving for setting of an average LED current as another input, and phase (or instantaneous voltage) information of the rectified AC as the third input for instantaneous AC current waveform shaping, and an output connected to the control terminal of the power switching device, and

A LED chain circuit by connecting several LEDs in series with a capacitor connecting in parallel with the series of LEDs, with a current flowing in terminal as a positive terminal, and a current leaving terminal as a negative terminal;

The LED chain circuit and the LED current control circuit are connecting in series and the whole circuit is connected between the positive and negative terminals of a rectified AC power source.

[0018] Optionally, a series diode to prevent the reverse current flow may be added either at the positive terminal or the negative terminal of the rectified AC power source, or between the LED chain circuit and the LED current control circuit.

[0019] Optionally, a filter circuit may be added between the connection of the three input error amplifier and the power switching device.

[0020] Preferably, the current sensing device can take the form of a simple resistor, or current mirror followed by current to voltage conversion, to produce a voltage representing the current flowing through the power switching device.

[0021] Preferably, the averaging circuit can take the form of passive low pass filter, or active low pass filter, or low pass filter with addition of sample and hold control for processing of the averaging function.

[0022] It is further disclosed herein a monolithic integrated circuit for direct drive LED light application comprising the following:

A power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and
A three input error amplifier with an output connected to the control terminal of the power switching device, an input connected to a reference voltage for setting the average current flowing through the power switching device, a second input for obtaining feedback information of the average current flowing through the power switching device, and a third input for instantaneous current waveform shaping.

[0023] Optionally, a filter circuit may be added between the connection of the error amplifier and the power switching device.

[0024] Preferably, an external current sensing device, averaging circuit, and LED chain circuit may be connected to produce intended application circuits.

Brief Description of the Drawings

[0025]

Fig.1 is a typical block diagram of control circuit for direct drive LED lighting.

Fig. 2 is the LED voltage and current versus the AC half cycle waveform for control circuit in Fig. 1.

Fig.3 is the invented control circuit for direct drive LED lighting with improved LED utilization and reduced flicker.

Fig. 4 is the waveforms for rectified AC voltage, AC line current and LED current for circuit shown in Fig. 3

Fig. 5 is an alternative circuit connection for achieving the same function as Fig.3 using the same circuit blocks.

Fig. 6 is the same as Fig.3 with the blocks that is possible to be integrated into a monolithic IC using ultra high voltage BCD process shown as a combined block.

Fig.7 is another invented control circuit for direct drive LED lighting with improved LED utilization, reduced flicker, and improved efficiency.

Figure 8 illustrates two preferred design embodiments for the three input error amplifiers in Fig. 7

Fig. 9 is the waveforms for rectified AC voltage, AC line current and LED current for circuit shown in Fig. 7 using a selected error amplifier from Fig. 8.

Fig. 10 is an alternative circuit connection for achieving the same function as Fig.7 using the same circuit blocks.

Fig. 11 is the same as Fig.7 with the blocks that is possible to be integrated into a monolithic IC using ultra high voltage BCD process shown as a combined block.

Figure 12 illustrates another two preferred design embodiments for the three input error amplifiers in Fig. 7 to provide additional efficiency improvement.

Fig. 13 is the waveforms for rectified AC voltage, AC line current and LED current for circuit shown in Fig. 7 using a selected error amplifier from Fig. 12.

Description of the Preferred Embodiment

[0026] To improve the LED utilization as well as reducing the flicker, a direct drive LED control circuit which has LED current conduction for the whole AC half cycle as well as having low LED current variation, and hence a low flicker index, is required. Fig. 3 is the block diagram for such a circuit.

[0027] In Fig. 3, current through the LEDs 303 and the capacitor 304 connected across the LEDs 303 during the period that the instantaneous AC input voltage is higher than the minimum LEDs' forward voltage is supplied by the rectified AC. When the instantaneous AC input voltage is below the LEDs' forward voltage, current to the LEDs 303 is supplied by the energy stored in the capacitor 304. Hence, the all off period for the LED chain is eliminated. The per half cycle LED current is controlled by sensing the current through the power switching device 305 via the current sensing device 306 (a resistor in this particular design embodiment), with an averaging circuit 301 to produce the feedback to error amplifier 302 for completing the feedback loop. Another input for setting the LED current is the internally generated Vref, which is connected to another input of error amplifier 302. Output of error amplifier 302 is directly connected, or optionally via a filter, to the control input of the power switching device 305. This feedback loop determines the current profile via power switching device 305, and hence the long term LED average current. Optionally, a series diode to block the reverse current flow may be added to the positive or negative side of the rectified AC power source, or between the parallel circuit formed by the LED chain 303 and the capacitor 304 and the power switching device 305.

[0028] Fig. 4 illustrates the AC half cycle voltage and current, as well as the LED current. It can be observed that the LED chain remains on for every full half cycle of AC as well as having relatively small current variation. Hence, flicker is reduced substantially as compared with the circuit shown in Fig.1. In addition, the LED utilization is practically near 100%. However, the power factor performance is not as good as the prior act (which is practically near 1) but still satisfactory (near 0.9 with proper selection of voltage of the LED chain). Major heat dissipation at regions near the peak of the AC half cycles is similar.

[0029] Instead of having the parallel circuit formed by LEDs 303 and capacitor 304 connected between the positive side of the recetified AC and the positive terminal of the power switching device 305 in Fig. 3, it is an alternative to connect this parallel circuit between the negative side of the current sensing deive and the negative terminal of the rectified AC power source, and the postive terminal of the power switching device is connecting to the positive terminal of the rectified AC power source. Fig. 5 illustrates this alternative interconnecting circuit for achieving the same function.

[0030] It is a preferred embodiment of this invention to integrate device 302 and 305 into a monolithic integrated circuit 607 as shown in Fig. 6 using ultra high voltage (500-700V) BCD processes that are available in recent years. The same monolithic circuit may be used to replace devices 502 and 505 in the circuit shown in Fig. 5.

[0031] A further innovation of this invention to reduce the heat dissipation at the power switching device. This is achieved by reducing the current flowing through the power switching device when the AC instantaneous voltage is above a selected value. During such period, the LED current is the sum of the AC input current plus the current supplied by the capacitor in parallel with the LED chain. While the instantaneous LED current is reduced during such period, the long term average LED current remains constant according to the target set by the reference voltage and sensed by the current sensing device. Fig. 7 illustrates a preferred design.

[0032] Fig. 7 is a modified version of Fig. 3 in which the two input error amplifier 302 is replaced by a three input error amplifier 702. Besides the original 2 inputs, a third input, which contains the voltage information of the AC line, is added to wave shape the AC current as described in the previous paragraph. When the AC instantantaneous voltage is above a pre-determined level, the AC input current is reduced according to the voltage in excess of the pre-selected level. This additional control signal has fast response and therefore modulates the AC line current immediately. While the signal for the third input pin of the error amplifier 702 is taken indirectly from the positive channel terminal of the power switching device in Fig. 7, it can also be optionally taken from from a resistor divider across the rectified AC power source. Preferred design embodiments for the three input amplifier 702 are shown in Fig. 8.

[0033] In Fig. 8(a), resistors 804, 805 and 805 divide down the signal from the positive channel terminal of the power switching device. Comparator 803 compares one of the divided down signal with Vref to generate a control signal for the analogue multiplexor MUX 802. When the AC instantaneous voltage is above a desired value, this control signal is a logical '1'. When the AC instantaneous voltage is below such desired value, this control signal is a logical '0'. When the control sign is '1', MUX 802 selects a divided down signal of the positive channel terminal of the power switching device (which carries the information of instantaneous rectified AC voltage) to its output terminal. When the control sign is logical '0', MUX 802 selects a ground potential to its output terminal. The output of the MUX 802 is summed with the output from the averaging circuit to generate the signal for one of the input of the error amplifier 807. Another input for error amplifier 807 is the Vref. Output of error amplifier 807 is then used to control the power switching device. With this circuit, current through the power switching device, and hence the AC line current, will be reduced near the peak of the AC cycle.

[0034] In Fig. 8(b), resistors 809, 810 and 811 divide down the signal from the positive channel terminal of the power switching device. Comparator 812 compares one of the divided down signal with Vref to generate a control signal for the analogue multiplexor MUX 813. When the AC instantaneous voltage is above a desired value, this control signal is a logical '1'. When the AC instantaneous voltage is below such desired value, this control signal is a logical '0'. When the control sign is logical '1', MUX 813 selects a divided down signal of the positive channel terminal of the power switching device to its output terminal. When the control sign is '0', MUX 813 selects a ground potential to its output terminal. The output of the MUX 813 is subtracted from the output of the error amplifier 808 to generate control signal for the power switching device. Error amplifier 808 takes the output from the averaging circuit and Vref as inputs for controlling the long term average LED current. With this circuit, current through the power switching device, and hence the AC line current, will be reduced near the peak of the AC cycle.

[0035] Fig. 9 shows waveforms of key circuit nodes of Fig.7. With the invented circuit using a selected error amplifier as shown in Fig. 8, the heat dissipation at the power switch near the peak voltage of the AC cycle is reduced and hence the efficiency is improved, at the expenses of lowering the power factor.

[0036] Instead of having the parallel circuit formed by LEDs 703 and capacitor 704 connected between the positive side of the recetified AC and the positive terminal of the power switching device 705 in Fig. 7, it is an alternative to connect this parallel between the negative side of the current sensing deive and the negative terminal of the rectified AC power source, and the postive terminal of the power switching device is connecting to the positive terminal of the rectified AC power source. Fig. 10 illustrates this alternative interconnecting circuit for achieving the same function.

[0037] It is another preferred embodiment of this invention to integrate device 702, and 705 into a monolithic integrated circuit 1107 as shown in Fig. 11 using ultra high voltage (500-700V) BCD processes that are available in recent years. The same monolithic circuit may be used to replace devices 1002 and 1005 in the circuit shown in Fig. 10.

[0038] As an extreme implementation of the previous implementation, instead of reducing the AC input current near the AC peak according to AC instantaneous voltage exceeding a selected level, AC current can be totally removed when the AC instantaneous voltage exceeds a selected level. This can totally eliminate the heat dissipation near the peak of the AC cycle, and hence improving the efficiency to the maximum according to the principle of this invention. Fig. 12 illustrates two preferred design embodiments for the three input error amplifier in Fig.7 and Fig. 10 to achieve the desired effect.

[0039] In Fig. 12(a), resistors 1203 and 1204 divide down the signal from the positive channel terminal of the power switching device. Comparator 1202 compares the divided down signal with Vref to generate a control signal for the analogue multiplexor MUX 1201. When the AC instantaneous voltage is above a desired value, this control signal is a logical '1'. When the AC instantaneous voltage is below such desired value, this control signal is a logical '0'. When the control sign is logical '1', MUX 1201 selects a logical '1', or the supply voltage for the control circuit, to its output terminal. When the control sign is logical '0', MUX 1201 selects the output from the averaging circuit to its output terminal. The output of the MUX 1201 and Vref are inputs for error amplifier 1205 to generate the control signal for the power switching device. With this circuit, current through the power switching device, and hence the AC line current, will be totally eliminated when the AC instantaneous voltage is above the desired value.

[0040] In Fig. 12(b), resistors 1207 and 1208 divide down the signal from the positive channel terminal of the power switching device. Comparator 1209 compares the divided down signal with Vref to generate a control signal for the analogue multipexor MUX 1210. When the AC instantaneous voltage is above a desired value, this control signal is a logical '1'. When the AC instantaneous voltage is below such desired value, this control signal is a logical '0'. When the control sign is logical '1', MUX 1210 selects a logical '0', or zero potential of the current control circuit, to its output terminal. When the control sign is '0', MUX 1210 selects the output from output of error amplifier 1206. The output of the MUX 1210 is used to control the power switching device. Error amplifier 1206 uses Vref and the output from the averaging circuit as inputs. With this circuit, current through the power switching device, and hence the AC line current, can be totally eliminated when the AC instantaneous voltage is above the desired value.

[0041] Fig. 13 shows waveforms of key circuit nodes of Fig.7. With the invented circuit using a selected three input error amplifier as shown in Fig. 12, the heat dissipation at the power switch is reduced and hence the efficiency is improved, at the expenses of lowering the power factor.

Claims

1. A direct drive LED lighting circuit comprising:

a LED current control circuit with a power switching device; a current sensing device, an averaging circuit, and an error amplifier; wherein

the power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and

a current sensing device for sensing the current flowing through the power switching device is connecting between the negative channel terminal of the power switching device and the reference node (lowest voltage) of the control circuit, the output of the current sensing device (or negative channel terminal of the power switching device for particular implementation) is also connecting to the input of an averaging circuit; and

the averaging circuit with an input connected to the output of the current sensing device, and an output connected to one of the inputs of an error amplifier; and

the error amplifier with an output of the averaging circuit as one of the inputs, and reference voltage serving for setting of an average LED current as another input, and an output connected to the control terminal of the power switching device; and

a LED chain circuit by connecting several LEDs in series with a capacitor connecting in parallel with the series of LEDs, with a current flowing in terminal as a positive terminal, and a current leaving terminal as a negative terminal;

the LED chain circuit and the LED current control circuit are connecting in series and the whole circuit is connected between the positive and negative terminals of a rectified AC power source.

2. The direct drive LED lighting circuit as in claim 1, wherein an optional series diode to prevent the reverse current flow is added either at the positive terminal or the negative terminal of the rectified AC power source, or between the LED chain circuit and the LED current control circuit.

3. The direct drive LED lighting circuit as in claim 1, wherein an optional filter circuit is added between the error amplifier and the power switching device.

4. The direct drive LED lighting circuit as in claim 1, wherein the current sensing device takes the form of a simple resistor, or current mirror followed by current to voltage conversion, to produce a voltage representing the current flowing through the power switching device.

5. The direct drive LED lighting circuit as in Claim 1, wherein the circuit takes the form of passive low pass filter, or active low pass filter, or low pass filter with addition of sample and hold control for processing of the averaging function.

6. A monolithic integrated circuit for direct drive LED light application comprising the following:

a power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and

an error amplifier with an output connected to the control terminal of the power switching device, an input connected to a reference voltage for setting the average current flowing through the power switching device, and another input for obtaining feedback information of the average current flowing through the power switching device.

7. The monolithic integrated circuit for direct drive LED light application as in claim 6, wherein an optional filter circuit is added between the error amplifier and the power switching device.

8. The monolithic integrated circuit for direct drive LED lighting application as in claim 6, wherein external current sensing device, averaging circuit, and LED chain circuit are connected to produce the application circuit as in claim 1.

9. A direct drive LED lighting circuit comprising:

a LED current control circuit with a power switching device; a current sensing device, an averaging circuit, and a three input error amplifier; wherein
the power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and
a current sensing device for sensing the current flowing through the power switching device is connecting between the negative channel terminal of the power switching device and the reference node (lowest voltage) of the control circuit, the output of the current sensing circuit (or negative channel terminal of the power switching device for particular implementation) is also connecting to the input of an averaging circuit; and
the averaging circuit with an input connected to the output of the current sensing device, and an output connected to one of the inputs of a three input error amplifier; and
the three input error amplifier with the output of the averaging circuit as one of the inputs, and reference voltage serving for setting of an average LED current as another input, and phase (or instantaneous voltage) information of the rectified AC as the third input for instantaneous AC current waveform shaping, and an output connected to the control terminal of the power switching device, and
a LED chain circuit by connecting several LEDs in series with a capacitor connecting in parallel with the series of LEDs, with a current flowing in terminal as a positive terminal, and a current leaving terminal as a negative terminal;
the LED chain circuit and the LED current control circuit are connecting in series and the whole circuit is connected between the positive and negative terminals of a rectified AC power source.

10. The direct drive LED lighting circuit as in claim 9, wherein an optional series diode to prevent the reverse current flow is added either at the positive terminal or the negative terminal of the rectified AC power source, or between the LED chain circuit and the LED current control circuit.

11. The direct drive LED lighting circuit as in claim 9, wherein an optional filter circuit is added between the connection of the three input error amplifier and the power switching device.

12. The direct drive LED lighting circuit as in claim 9, wherein the current sensing device takes the form of a simple resistor, or current mirror followed by current to voltage conversion, to produce a voltage representing the current flowing through the power switching device.

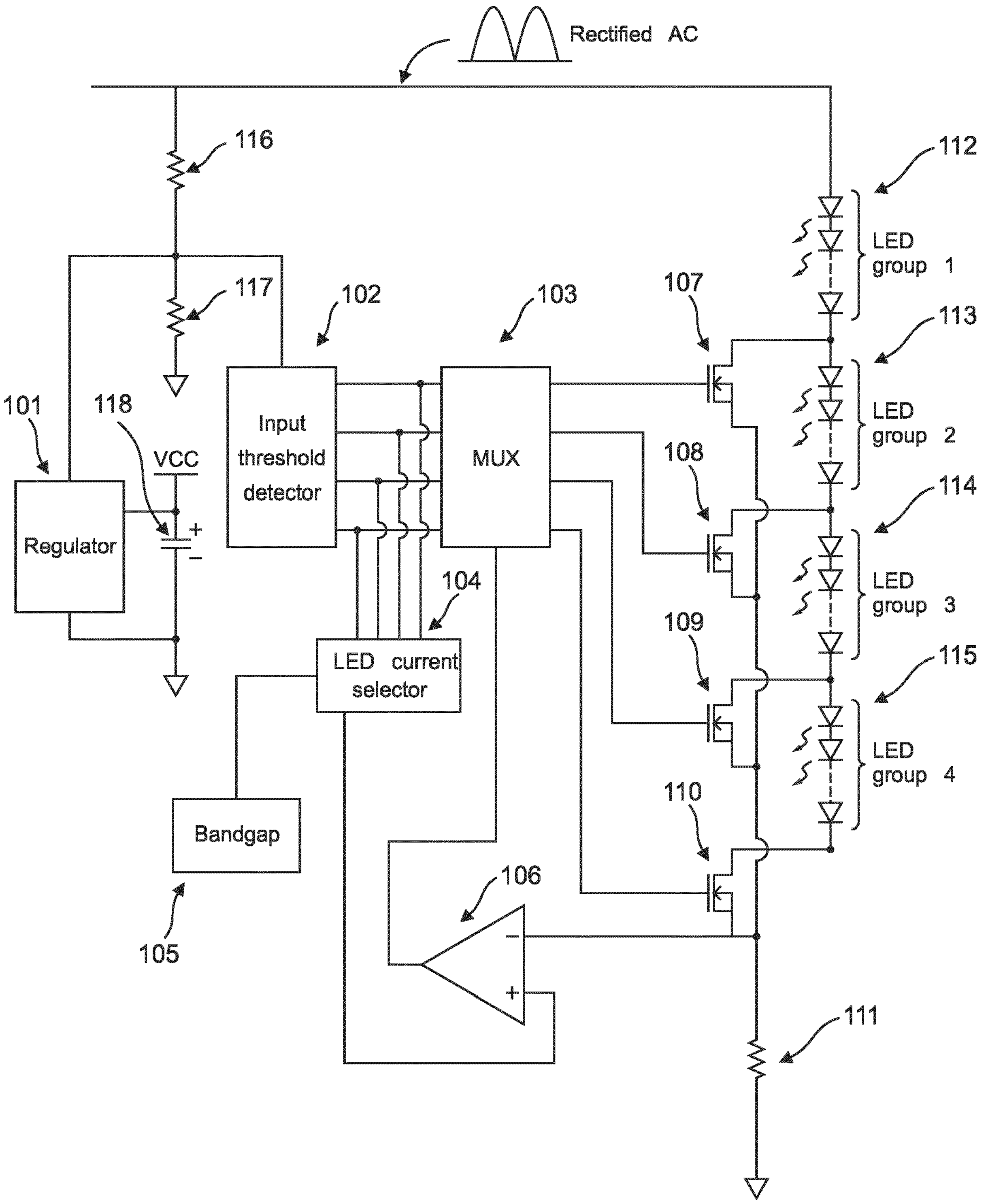
13. The direct drive LED lighting circuit as in Claim 9, wherein the averaging circuit takes the form of passive low pass filter, or active low pass filter, or low pass filter with addition of sample and hold control for processing of the averaging function.

14. A monolithic integrated circuit for direct drive LED light application comprising the following:

a power switching device with a control terminal to control the amount of current flowing through the switching channel, a current inflow terminal and a current outflow terminal as the positive channel terminal and the negative channel terminal of the power switching device respectively; and
a three input error amplifier with an output connected to the control terminal of the power switching device, an input connected to a reference voltage for setting the average current flowing through the power switching device, a second input for obtaining feedback information of the average current flowing through the power switching device, and a third input for instantaneous current waveform shaping.

15. The monolithic integrated circuit for direct drive LED light application as in claim 14, wherein an optional filter circuit is added between the connection of the error amplifier and the power switching device.

16. The monolithic integrated circuit for direct drive LED lighting application as in claim 14, wherein external current sensing device, averaging circuit, and LED chain circuit are connected to produce the application circuit as in claim 14.


Rectified AC
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112
LED group 1
117
102
103
107
113
101
118
VCC
Input threshold detector
MUX
LED group 2
108
114
Regulator
+
−
104
LED group 3
109
115
LED current selector
LED group 4
110
Bandgap
106
105
−
+
111

Fig. 1

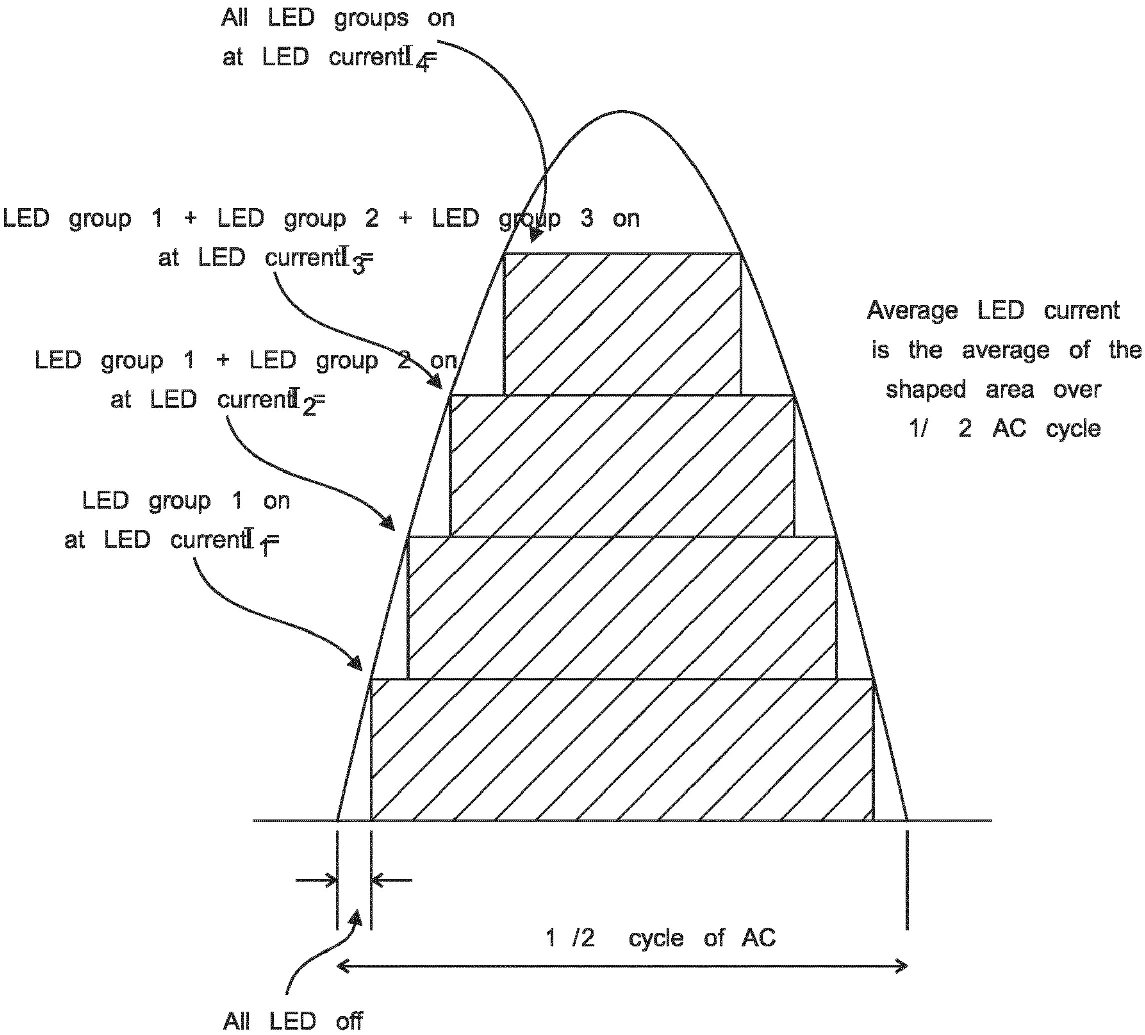
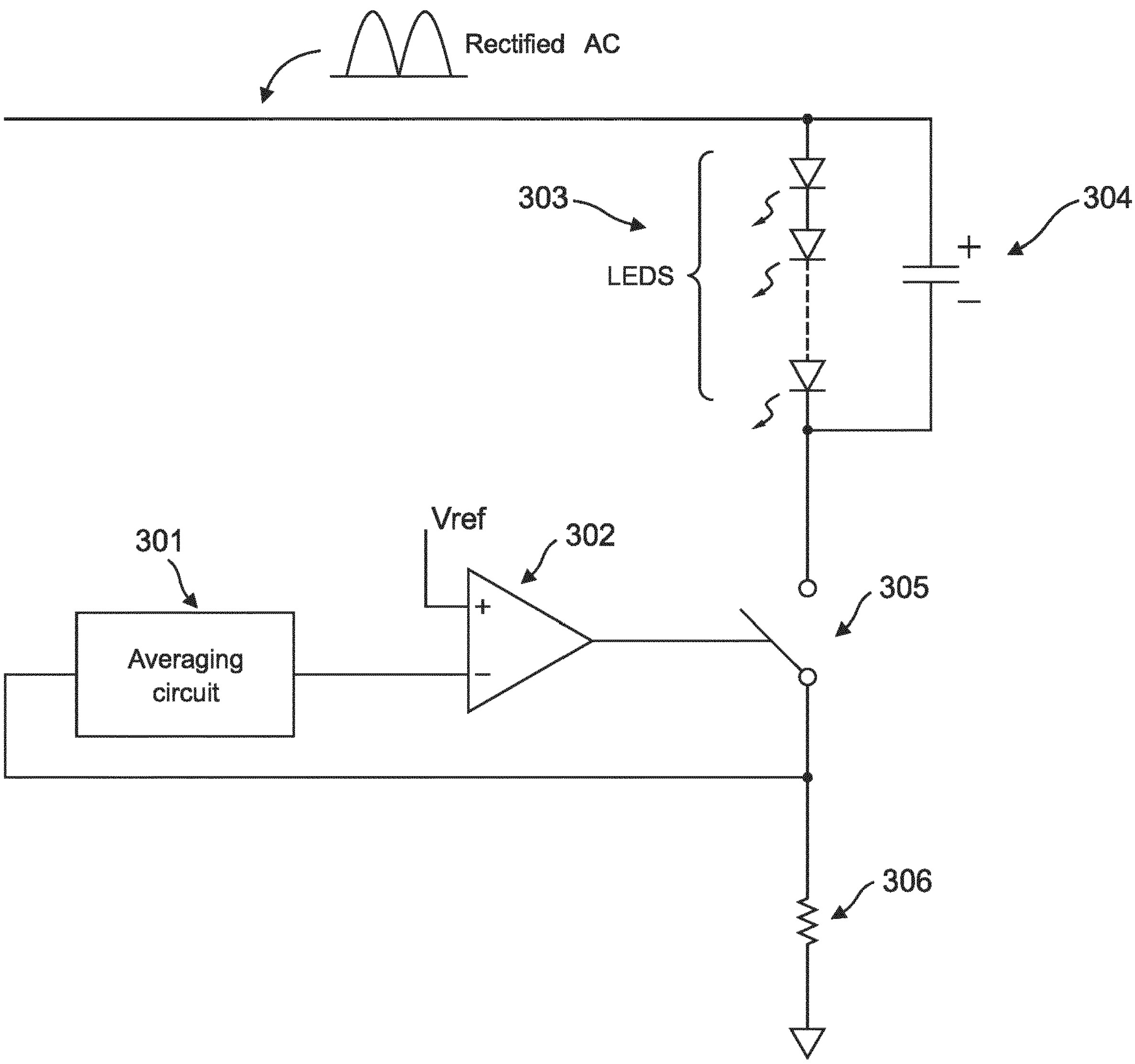

All LED groups on
at LED current I4
LED group 1 + LED group 2 + LED group 3 on
at LED current I3
LED group 1 + LED group 2 on
at LED current I2
LED group 1 on
at LED current I1
Average LED current
is the average of the
shaped area over
1/ 2 AC cycle
1 /2 cycle of AC
All LED off

Fig. 2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304
+
−
Vref
301
302
305
Averaging circuit
+
−
306

Fig. 3

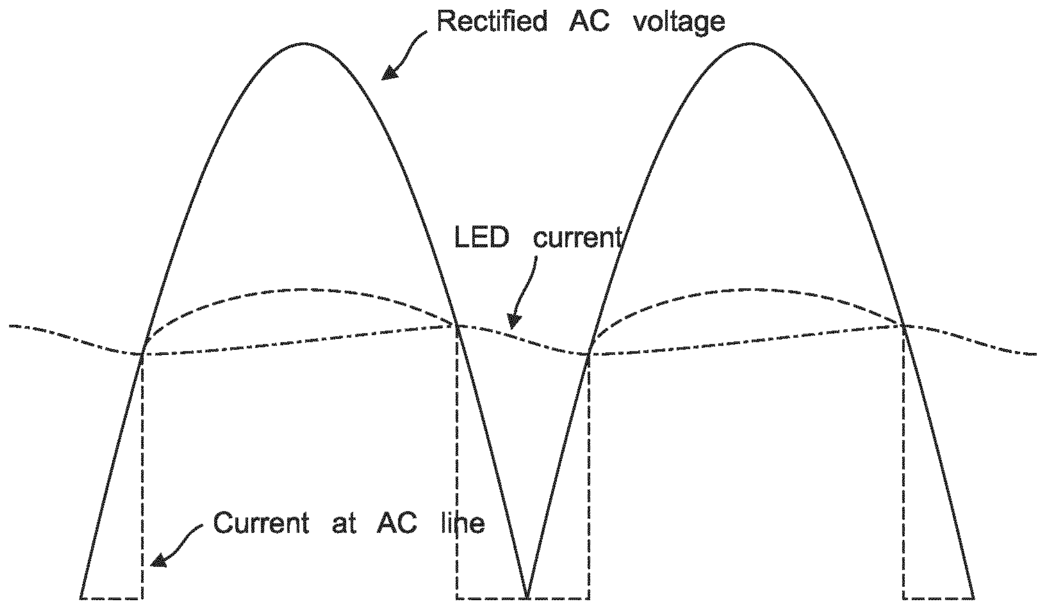
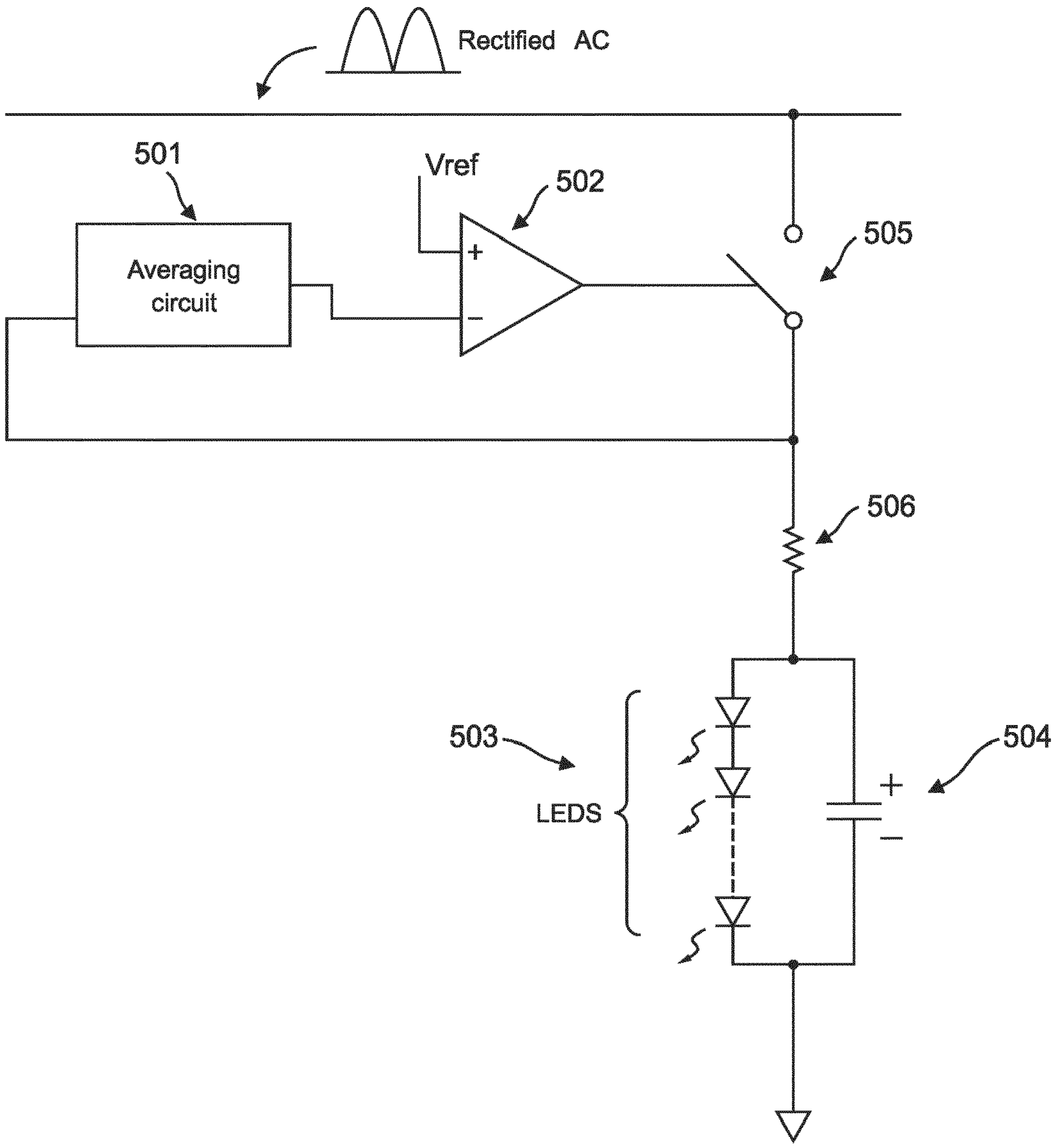


Fig. 4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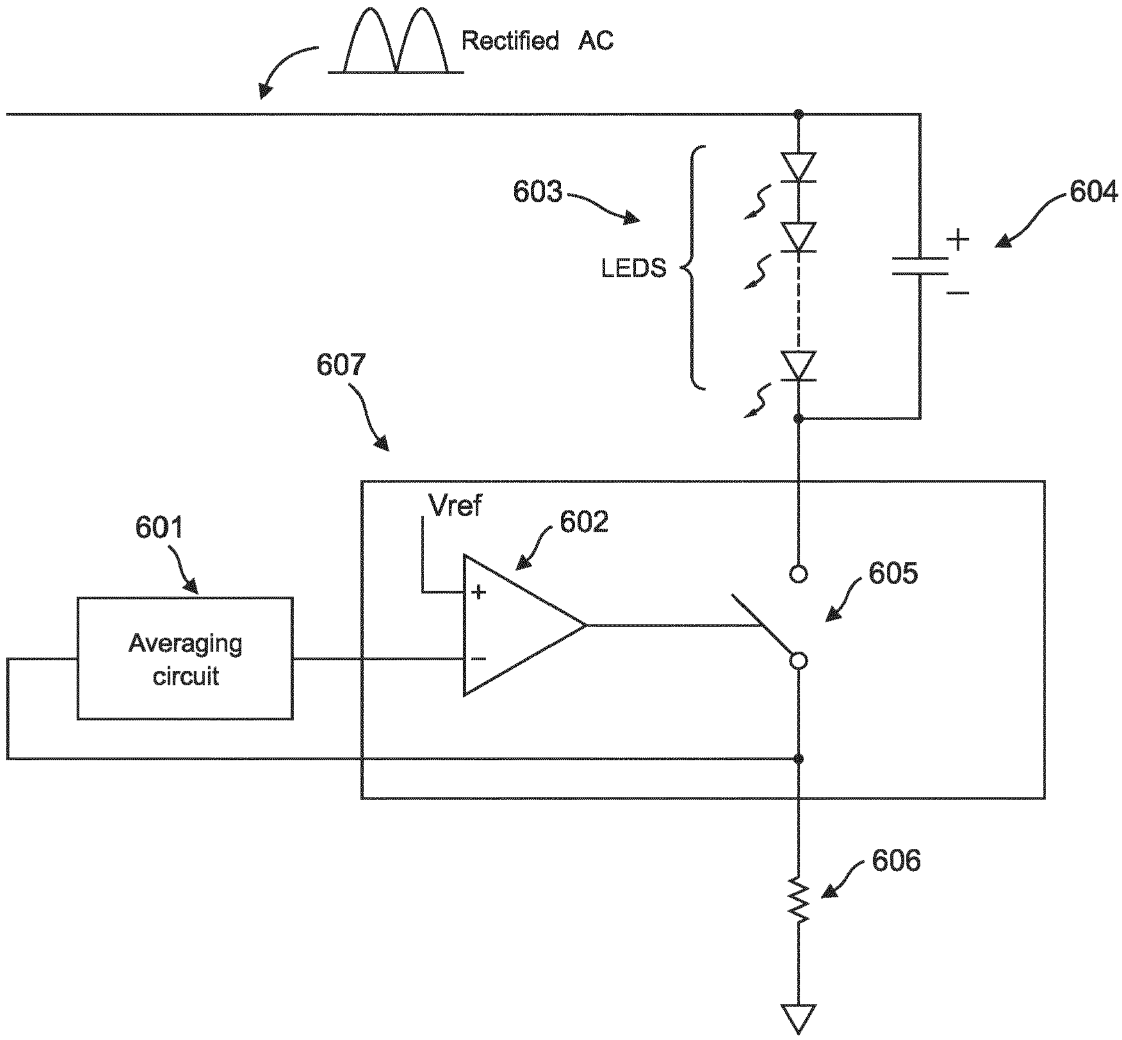
Averaging circuit
Vref
502
+
−
505
506
503
LEDS
504
+
−

Fig. 5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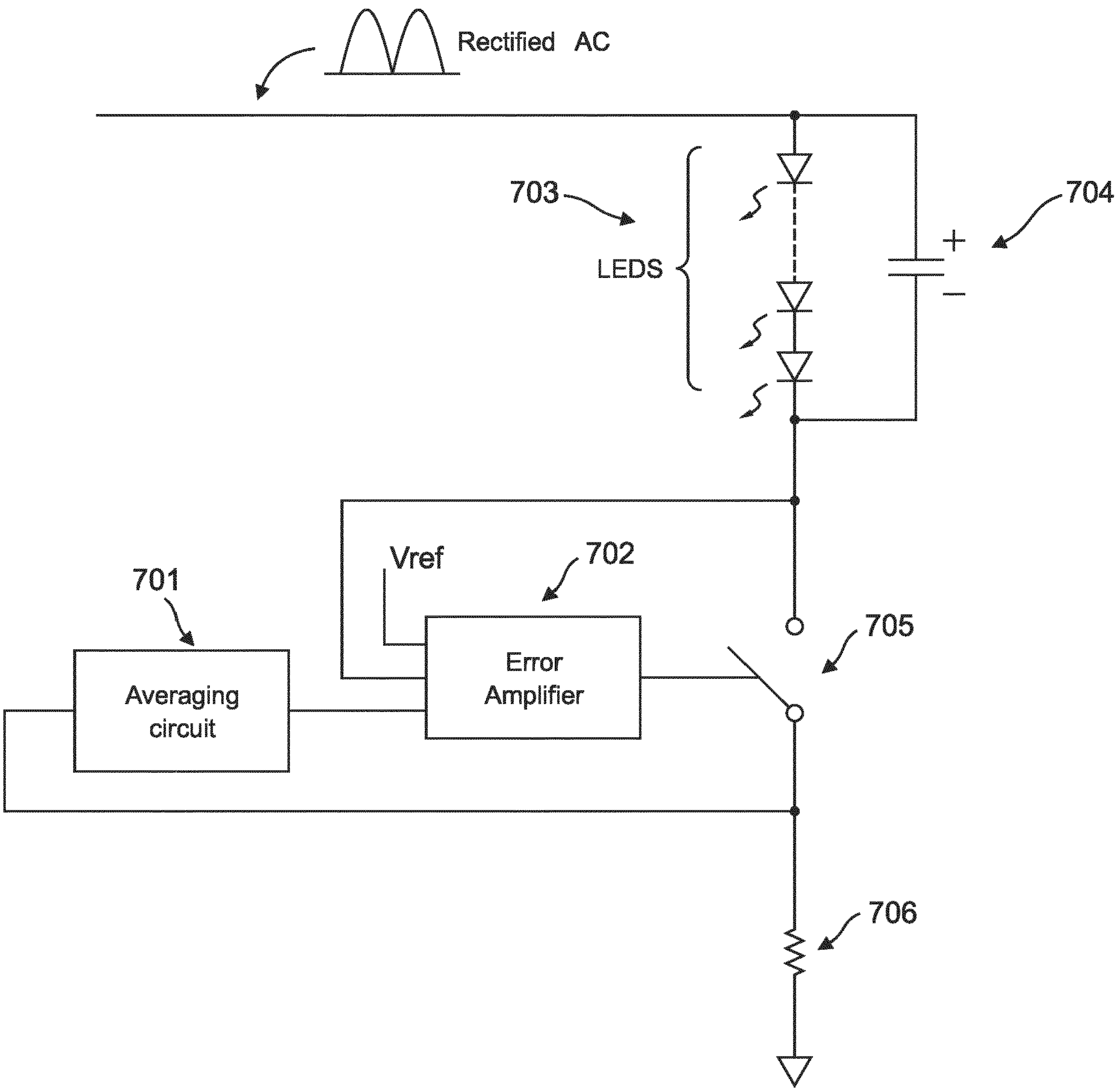
LEDS
604
+
−
607
Vref
602
601
605
Averaging circuit
+
−
606

Fig. 6


Rectified AC
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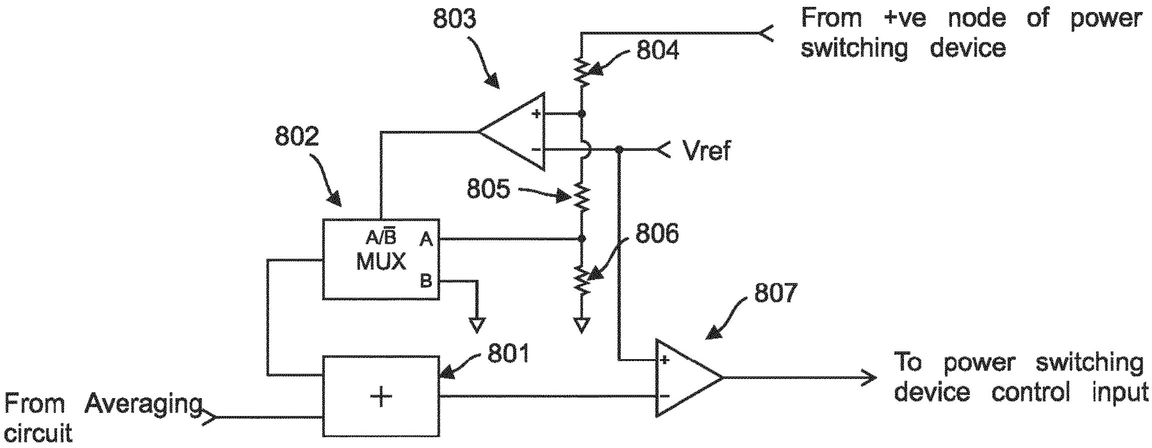
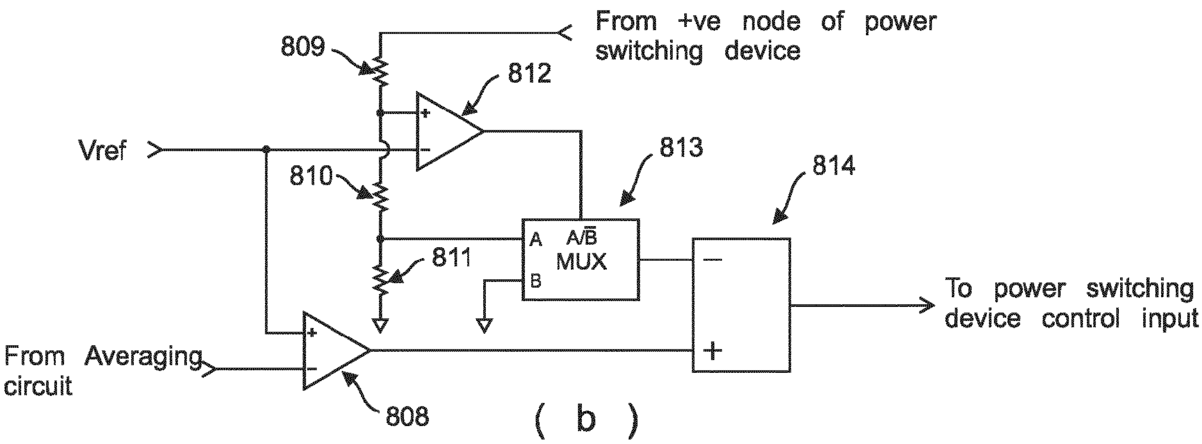
LEDS
704
+
−
Vref
702
701
705
Error Amplifier
Averaging circuit
706

Fig. 7


803
From +ve node of power switching device
804
802
Vref
805
A/B̄
MUX
A
B
806
807
801
+
From Averaging circuit
To power switching device control input

(a)


From +ve node of power switching device
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812
Vref
813
814
810
A
A/B̄
MUX
B
811
–
+
From Averaging circuit
To power switching device control input
808

(b)

Fig. 8

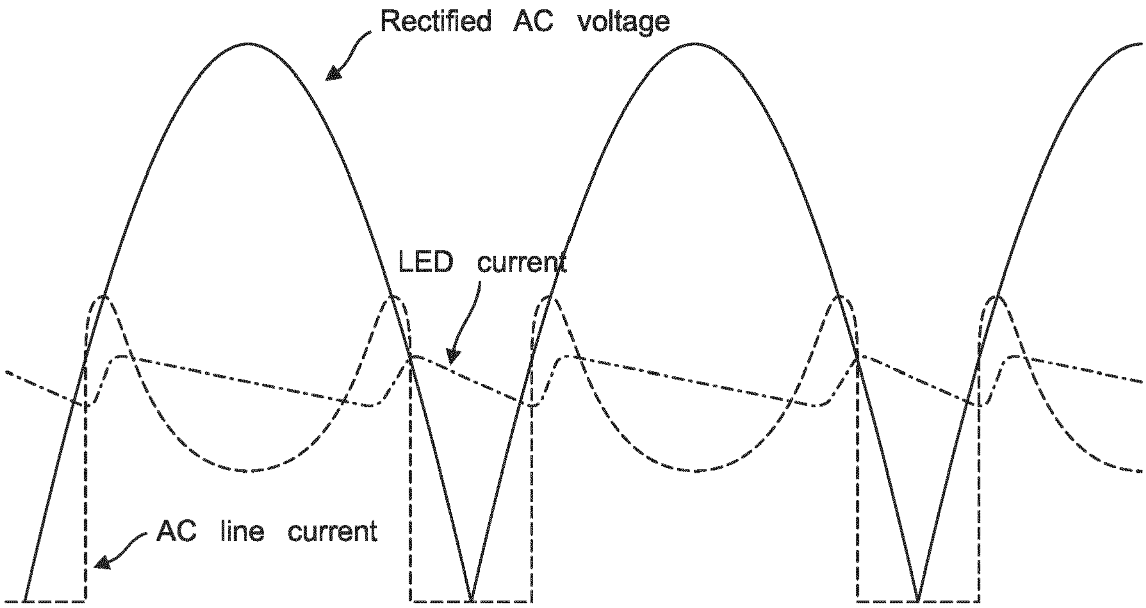

Fig. 9

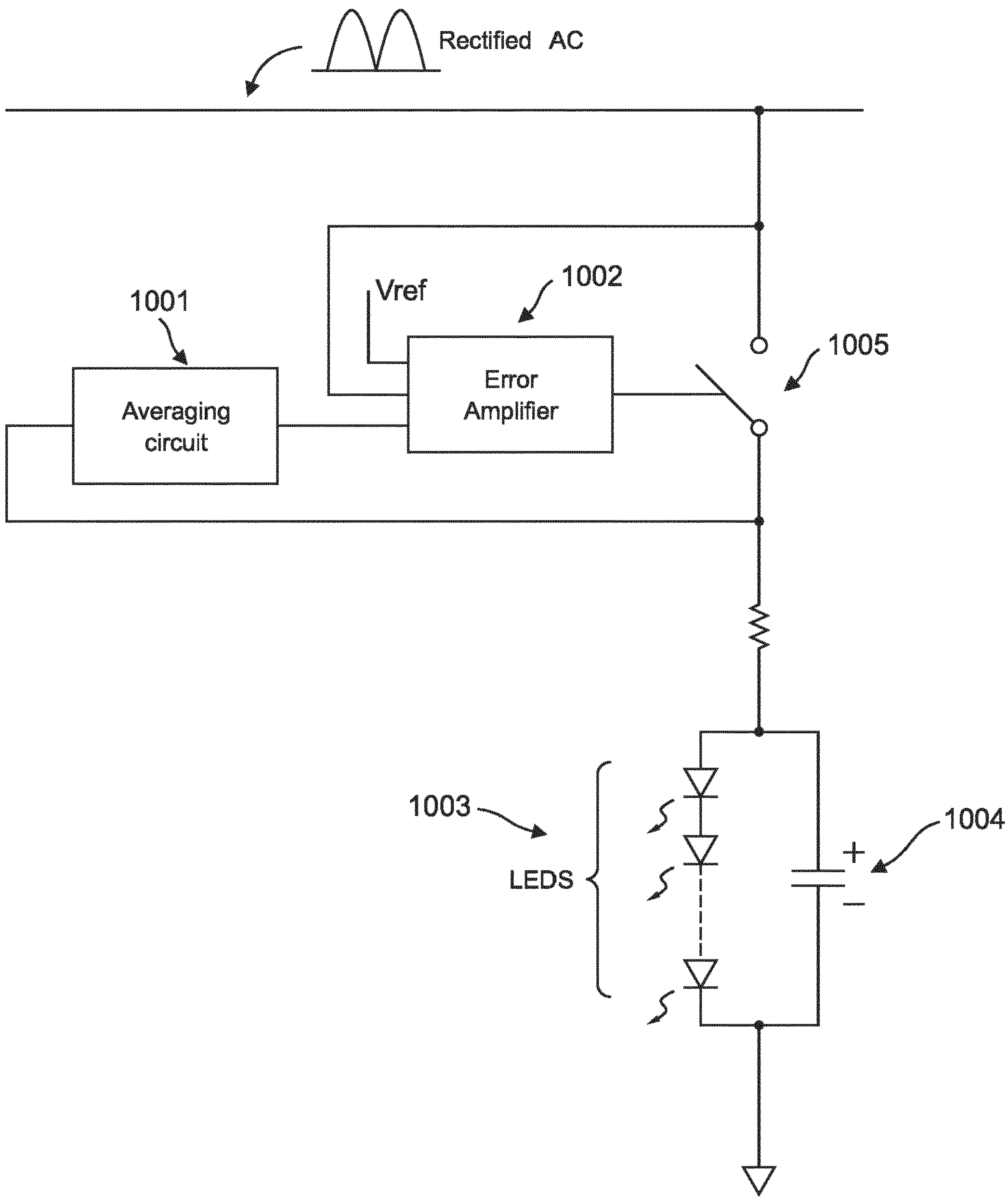
Rectified AC
1001
Averaging circuit
Vref
1002
Error Amplifier
1005
1003
LEDS
1004
+
−

Fig. 10

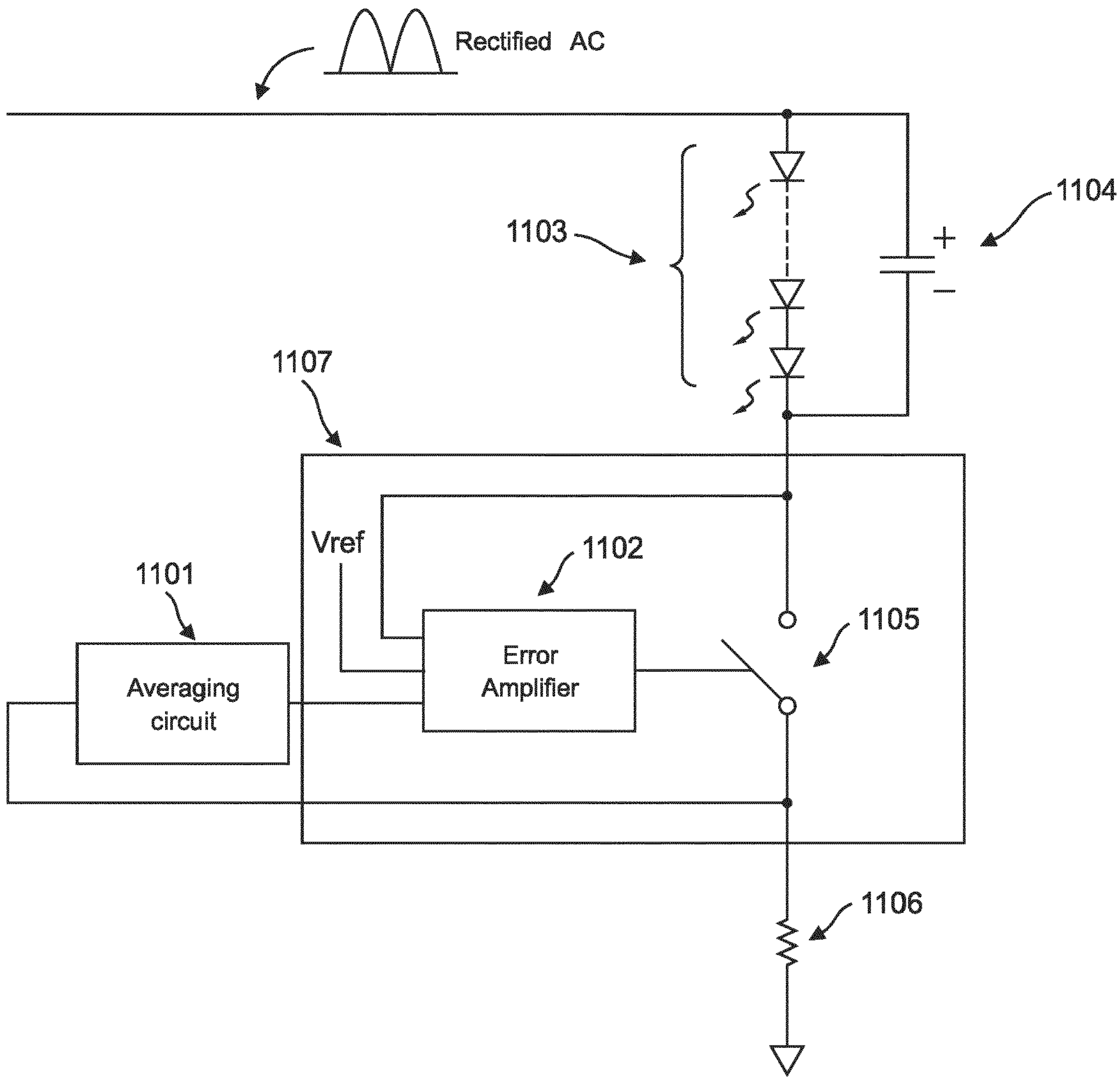
Rectified AC
1103
1104
+
−
1107
Vref
1102
1101
1105
Error
Amplifier
Averaging
circuit
1106

Fig. 11

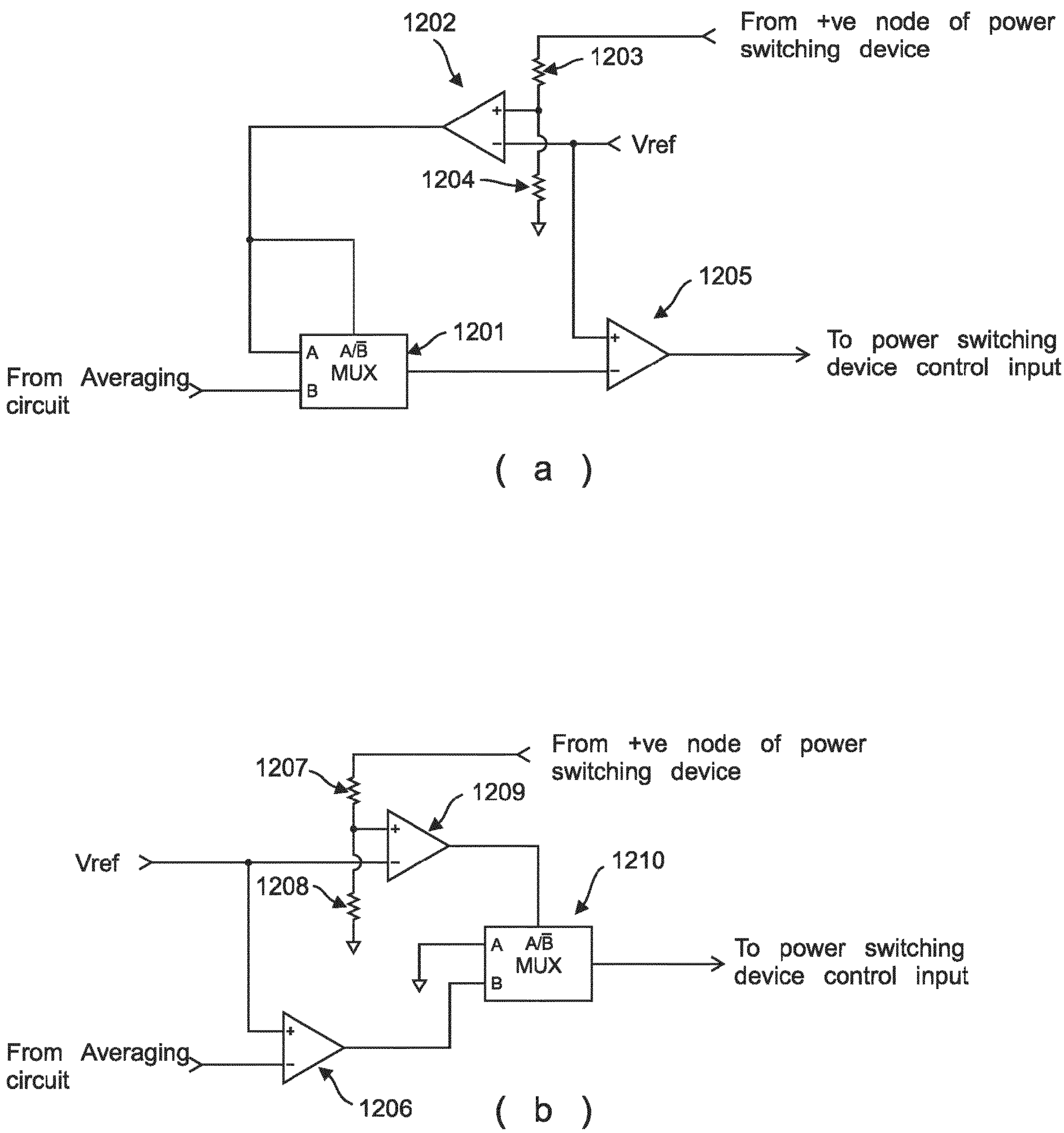
1202
From +ve node of power switching device
1203
Vref
1204
1205
1201
A A/B̄ MUX B
From Averaging circuit
To power switching device control input
(a)
From +ve node of power switching device
1207
1209
Vref
1208
1210
A A/B̄ MUX B
To power switching device control input
From Averaging circuit
1206
(b)

Fig. 12

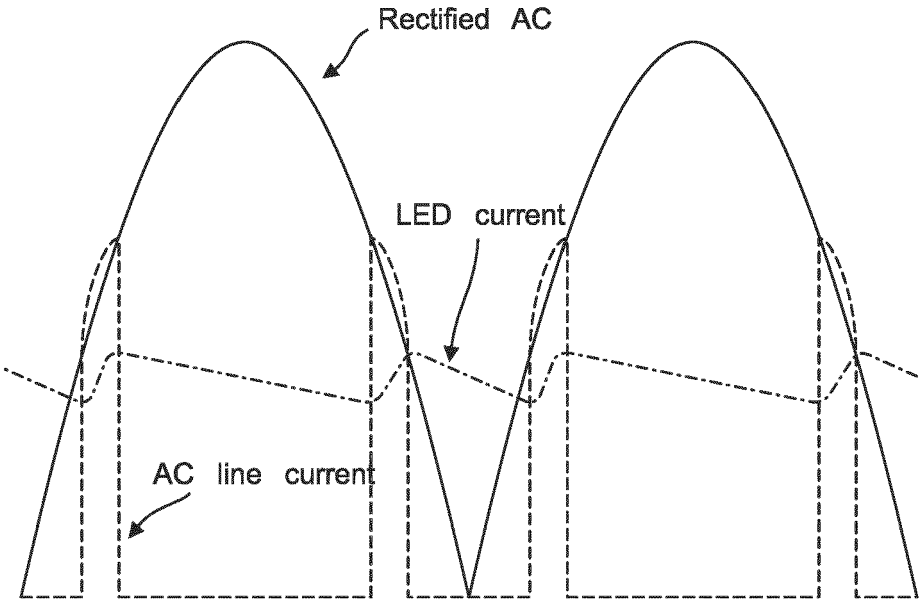

Fig. 13

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 4276

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H05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	17 November 2016	Brosa, Anna-Maria

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