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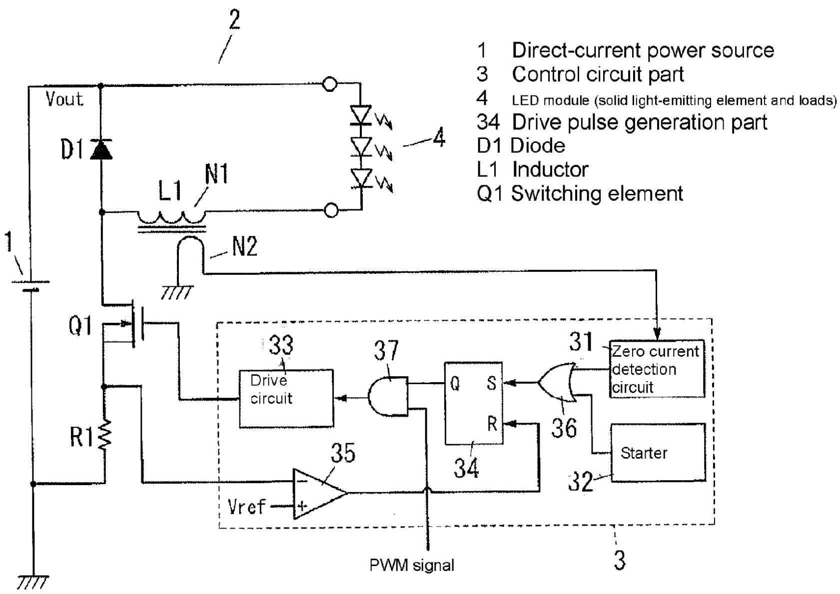
(54) **Solid light-emitting element lighting device and illumination fixture using the same**

(57) [Object] To provide a solid light-emitting element lighting device and an illumination fixture using the same that are able to smoothly change an optical output in sweeping of a PWM signal for dimming.

[Means for Settlement] A LED lighting device includes: a series circuit of an inductor L1 and a switching element Q1 that are connected between output terminals of a direct-current power source 1 via a LED module 4; a diode D 1 for regenerating energy accumulated in the inductor L1 to the LED module 4; and a control circuit part 3 for controlling on and off of the switching element Q1. The control circuit part 3 includes a drive signal generation part 34 for generating a drive pulse whose pulse width varies in accordance with amplitude of a load current, and controls on and off of the switching element Q1 due to the drive pulse in an on-period of the PWM signal whose on-duty varies in accordance with a dimming level, the PWM signal being a lower frequency than the drive pulse. An output voltage of the direct-current power source 1 is set to be larger than the load voltage applied to the LED module 4 and to be 2.5 times as large as the load voltage or less.

Figure 1



EP 2 519 079 A1

Description

[Field of the Invention]

[0001] The present invention relates to a solid light-emitting element lighting device and to an illumination fixture using the same.

[Background Art]

[0002] Conventionally, an LED lighting device for supplying lighting power to an LED illumination module is provided (for example, refer to Patent Literature 1). As shown in Fig. 7, the LED lighting device includes: a control switch Q3 for being turned on and off in accordance with a dual signal including a low-frequency burst of high-frequency pulse, the control switch Q3 being connected to an LED illumination module 104 in series; an inductor L2 for accumulating energy when the control switch Q3 is turned on, the inductor similarly being connected to the LED illumination module 104 in series; and a diode D2 for regenerating the energy accumulated in the inductor L2 to the LED illumination module 104 at the turning-off of the control switch Q3. The above-mentioned dual signal is an AND output of a high-frequency drive pulse and a low-frequency PWM signal to the control switch Q3, an average current flowing to the LED illumination module 104 is varied by changing a duty ratio of the PWM signal, and thus a light intensity outputted from the LED illumination module 104 is changed (so-called burst dimming).

[Conventional Technique Document]

[Patent Literature]

[0003] [Patent Literature 1] JPT 2006-511078 (Paragraph [0015] to [0017] and Fig. 7 to Fig. 9)

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0004] In the LED lighting device shown in above-mentioned Patent Literature 1, the high-frequency drive pulse to the control switch Q3 is the AND output including the low-frequency PWM signal, and when an edge of the above-mentioned PWM signal is inputted during the turning-on of the control switch Q3, the drive pulse to the control switch Q3 becomes Low. Specifically, the on-period of the control switch Q3 is changed due to the variation of the low-frequency PWM signal, and accordingly an LED current, that is, an optical output of the LED illumination module 104 varies. On the other hand, during the off-period of the control switch Q3, the regeneration current of the inductor L2 flows to the LED illumination module 104 via the diode D2; however, even when the above-mentioned PWM signal varies, the LED current does not change during the period. That is, despite the variation of the PWM signal, the optical output of the LED module 104 does not change.

[0005] Fig. 8 is a time chart of the case where the control switch Q3 is operated in a critical mode (a mode in which the control switch Q3 is switched from being turned off to being turned on at timing when the current flowing to the inductor L2 becomes zero). As shown in Fig. 8, in the case where the PWM signal changed from the solid line to the broken line, that is, in the case where the on-period of the PWM signal becomes long, a load current I1 of the LED illumination module 104 will increases by one cycle of the drive signal (the broken line in Fig. 8). In addition, since the larger a difference between an input voltage and an output voltage is, the more a slope of the current at the turning-on of the control switch Q3 becomes steep, in the case of obtaining the same output, the on-period will be short, and thus the off-period of the control switch Q3 is lengthened by the shortened on-period to extend the regeneration period (refer to the drive signal in Fig. 8).

[0006] Accordingly, since the optical output does not vary during the off-period of the control switch Q3 even in the case of trying to smoothly change a dimming level, for example, by sweeping the duty of the above-mentioned PWM signal, the optical output to the duty variation will be stepwise as shown in Fig. 9. Then, the optical output difference of the one step is equivalent to the optical output of the one cycle of the high-frequency drive pulse for the control switch Q3, and accordingly the stepwise variation of the optical output can be watched. Specifically, since a variation rate of the optical output at the sweeping is large under a low light flux state, the stepwise variation will be more apparent.

[0007] As described above, in the case where the difference between the input voltage and the output voltage is large, the ratio of the period where the optical output does not vary in the sweeping of the PWM signal is large, and consequently there causes a problem that the optical output appears to vary in a stepwise fashion.

[0008] The present invention is achieved in consideration of the above-mentioned problems, and a purpose of the present invention is to provide a solid light-emitting element lighting device and an illumination fixture using the same that are able to smoothly change the optical output in the sweeping of the PWM signal for dimming.

[Means adapted to solve the Problems]

[0009] A solid light-emitting element lighting device of the present invention includes: a series circuit of an inductor and a switching element that are connected between output terminals of a direct-current power source via a load; a diode for regenerating, during turning-off of the switching element, energy accumulated during turning-on of the switching element in the inductor to the load; and a control circuit part for controlling on and off of the switching element, wherein the control circuit part includes a drive signal generation part for generating a drive signal whose pulse width varies in accordance with an amplitude of a load current, and controls the on and off of the switching element due to the drive signal in an on-period or an off-period of the PWM signal whose on-duty varies in accordance with a dimming level, the PWM signal being a lower frequency than the drive signal, and an output voltage of the direct-current power source is set to be larger than the load voltage applied to the load and to be 2.5 times as large as the load voltage or less.

[0010] In the solid light-emitting element lighting device, it is preferred that the control circuit part includes a zero current detection circuit for detection that a current flowing to the inductor becomes zero, and switches the switching element from being turned off to being turned on in synchronization with detection timing of the zero current detection circuit.

[0011] Additionally, in the solid light-emitting element lighting device, it is preferred that the control circuit part switches the switching element to be turned on before the current flowing to the inductor during the turning-off of the switching element becomes zero.

[0012] Moreover, in the solid light-emitting element lighting device, it is preferred that the direct-current power source includes an AC-DC converter or a DC-DC converter to which a detection result of the load voltage is feed backed and that controls an output voltage to be a voltage proportional to the detection result, and includes a voltage detection part for detecting the load voltage and feed backing the load voltage to the direct-current power source.

[0013] Furthermore, in the solid light-emitting element lighting device, it is preferred that the direct-current power source includes the AC-DC converter, and a frequency of the PWM signal is set to 600Hz or multiples of 600Hz.

[0014] An illumination fixture of the present invention includes: the solid light-emitting element lighting device according to any one of claims 1 to 5; and a solid light-emitting element to which lighting power is supplied from the solid light-emitting element lighting device.

[Effect of the Invention]

[0015] An effect to provide a solid light-emitting element lighting device and an illumination fixture using the same that are able to smoothly change the optical output in the sweeping of the PWM signal for dimming can be obtained.

[Brief Description of the Drawings]

[0016]

[Fig. 1] Fig. 1 is a schematic circuit diagram showing a LED lighting device according to a first embodiment.
[Fig. 2] Fig. 2 is a time chart for explaining an operation of the above-mentioned device.
[Fig. 3] Fig. 3 is a graph for explaining the operation of the above-mentioned device.
[Fig. 4] Fig. 4 is a schematic circuit diagram showing another example of the above-mentioned LED lighting device.
[Fig. 5] Fig. 5 is a schematic circuit diagram showing an LED lighting device according to a second embodiment.
[Fig. 6] Fig. 6 is a schematic circuit diagram showing another example of the above-mentioned LED lighting device.
[Fig. 7] Fig. 7 is a schematic circuit diagram showing a conventional LED lighting device.
[Fig. 8] Fig. 8 is a time chart for explaining an operation of the above-mentioned device.
[Fig. 9] Fig. 9 is a graph for explaining the operation of the above-mentioned device.

[Best Mode for Carrying Out the Invention]

[0017] On the basis of drawings, embodiments of an illumination fixture using a LED lighting device will be explained below.

(First embodiment)

[0018] Fig. 1 is a schematic circuit view showing an LED lighting device (a solid light-light emitting device lighting device) according to a first embodiment. The LED lighting device includes: a step-down chopper circuit part 2 for stepping down an output voltage of a direct-current power source 1 to a direct current of a desired voltage value; and a control circuit part 3 for controlling a switching element Q1 to be turned on and off, the switching element Q1 described later constituting the step-down chopper circuit part 2. In addition, an illumination fixture according to the present embodiment includes: the LED lighting device; and a LED module (a solid light-emitting element, a load) 4 to which lighting power is supplied from the LED lighting device. Meanwhile, in the present embodiment, the LED module 4 includes three LEDs (light-emitting diodes); however, the number of LEDs is not limited to the present embodiment, and may be one, two, four or more.

[0019] The step-down chopper circuit part 2 includes: a series circuit of an inductor L1 and the switching element Q1, the series circuit being connected between output terminals of the direct-current power source 1 via the LED module 4; and a diode D1 for regenerating energy during the turning-off of the switching element Q1, the energy being accumulated in the inductor L1 during the turning-on of the switching element Q1.

[0020] The control circuit part 3 includes: a starter 32 for outputting a start-up signal to generate a drive pulse during stopping of oscillation at regular intervals; a zero current detection circuit 31 for detecting that a current flowing to a secondary wiring N2 of the inductor L1 becomes zero; and a drive pulse generation part 34 for generating the drive pulse to turn on and off the switching element Q1. In addition, the control circuit part 3 includes: a drive circuit 33 for driving the switching element Q1 in response to the drive pulse from the drive pulse generation part 34; a comparator 35 for outputting a reset signal to the drive pulse generation part 34 when a current flowing to the switching element Q1 reaches a reference value.

[0021] In the present embodiment, the drive pulse generation part 34 includes a RS flip-flop; to a set terminal of the RS flip-flop, an OR output of a detection signal of the zero current detection circuit 31 and the start-up signal of the starter 32 is inputted via an OR circuit 36, and an output of the drive pulse generation part 34 becomes High when the set signal is inputted. In addition, the output of the drive pulse generation part 34 becomes Low when the reset signal is inputted from the comparator 35, and thus a high-frequency drive pulse where the High and Low are alternately repeated is outputted from the drive pulse generation part 34.

[0022] Additionally, to the drive circuit 33, an AND output of: the high-frequency drive pulse inputted from the drive pulse generation part 34 and the lower-frequency PWM signal than the drive pulse is inputted via an AND circuit 37, and the drive circuit 33 controls the switching element Q 1 to be turned on and off in accordance with the AND output. Here, the above-mentioned drive pulse changes the pulse width on the basis of amplitude of a load current flowing to the LED module 4, and the above-mentioned PWM signal changes the on-duty on the basis of a dimming level. Meanwhile, a resistance R1 in Fig. 1 is a resistance for current detection to detect the current flowing to the switching element Q1.

[0023] Next, an operation of the LED lighting device will be explained. When the reset signal is inputted to the drive pulse generation part 34 due to an output signal from the starter 32 or the zero current detection circuit 31 during a period where the above-mentioned PWM signal is High, the output of the drive pulse generation part 34 becomes High, the switching element Q1 is turned on via the drive circuit 33, and thus a current flows to light the LED module 4. On this occasion, a temporal change of the load current I1 flowing to the switching element Q1 is shown as follows.

[Expression 1]

$$I1 = \frac{Vout - V1}{L1} t \qquad \cdots\cdots (1)$$

where in expression 1, Vout represents the output voltage of the direct-current source 1, V1 represents the load voltage of the LED module 4, t represents an elapsed time, L1 represents an impedance of the inductor, and a starting time of the turning-on of the switching element Q1 is t = 0.

[0024] When a voltage between both ends of the resistance R1 (that is, I1 × R1) reaches a reference voltage Vref, the output of the comparator 35 is inverted, the reset signal is inputted to the drive pulse generation part 34, the output of the drive pulse generation part 34 becomes Low, and thus the switching element Q1 is turned off. When the switching element Q1 is turned off, the energy accumulated in the inductor L1 is regenerated to the LED module 4, and thus the LED module 4 is lighted by the regeneration current. On this occasion, the temporal change of the current I2 flowing to the inductor L1 is represented as follows.

[Expression 2]

$$I2 = -\frac{V1}{L1}(t - Ton) + Idp \quad \cdots\cdots (2)$$

where in expression 2, Ton represents the on-period of the switching element Q1 and Idp represents a peak current flowing to the inductor L1.

[0025] And, when the current I2 flowing to the inductor L1 during the turning-off of the switching element Q1 becomes zero, thereby inverting the current due to a function of the inductor L1, the electric charge charged in the switching element Q1 is discharged. As the result, the voltage between the drain and source of the switching element Q1 is decreased, and the voltage of the inductor L1 is inverted. The zero current detection circuit 31 detects the voltage inverting and outputs the set signal to the drive pulse generation part 34, and thereby the switching element Q1 is turned on again at near zero of the current I2 flowing to the inductor L1. Then, the chopper operation is realized by repeating a series of the operations. Here, in the present embodiment, the switching element Q1 is switched from being turned off to being turned on at timing when the current I2 flowing to the inductor L1 becomes zero, and the mode is referred to as a critical mode.

[0026] On the other hand, when the above-mentioned PWN signal becomes Low, it is stopped to input the drive pulse to the drive circuit 33, and accordingly the oscillation is stopped during the period, that is, a state where the LED module 4 is lighted off is produced. Then, by varying the on-duty of the above-mentioned PWM signal, a ratio between a lighting-on state and the lighted-off state is changed, and consequently the output of the LED module 4 can be controlled.

[0027] Meanwhile, even if the above-mentioned PWM signal is varied during the off-period of the switching element Q1, the load current I1 flowing to the LED module 4 does not change. That is, even when the on-duty of the PWM signal is varied, the optical output of the LED module 4 does not change. Here, the on-period Ton and on-period Toff of the switching element Q1 are represented as follows in accordance with expression (1) and expression (2).

[Expression 3]

$$Ton = \frac{L1}{Vout - V1} Idp \quad \cdots\cdots (3)$$

[Expression 4]

$$Toff = \frac{L1}{V1} Idp \quad \cdots\cdots (4)$$

[0028] And, the on-duty Don of the switching element Q1 is represented as follows in accordance with expression (3) and expression (4).

[Expression 5]

$$Don = \frac{Ton}{Ton + Toff} = \frac{V1}{Vout} \quad \cdots\cdots (5)$$

According to expression (5), it is found that the on-duty of the switching element Q1 is determined only by: the output voltage Vout of the direct-current power source 1 and the load voltage V1 of the LED module 4.

[0029] Here, when the output voltage Vout of the direct-current power source 1 is defined as "Vout = K × V1", K =

1/Don is drawn from expression (5). Fig. 2 is a time chart for explaining the operation of the LED lighting device according to the present embodiment, and shows a case of K = 1.2. As will be understood in comparison with Fig. 8, since the off-period Toff of the switching element Q1 is very short in comparison with the on-period Ton, the load current I1 of the LED module 4 is slightly increased even when the PWM signal is varied, for example, from a solid line to a broken line. And accordingly the rapid change of the optical output can be suppressed.

[0030] Fig. 3 shows change of the optical output to the duty ratio of the PWM signal, and a solid line b in Fig. 3 shows the above-mentioned conventional LED lighting device, which corresponds to K = 10 in this case. A dashed line c in Fig. 3 corresponds to K = 1.1, the optical output substantially continuously changes in accordance with the variation of the duty ratio, and thus the stepwise changing of the optical output can be reduced even in the extraordinary deep dimming level. Additionally, a broken line d in Fig. 3 corresponds to K = 2.5, a period where the optical output is constant is approximately 60% on this occasion; however, the optical output variation is slower in comparison with the case of K = 10. In this case, the optical output appears to change in a stepwise fashion when the LED module 4 is directly looked; however, the change was in a level where the change cannot be recognized on an irradiation surface of the light as a flicker. Meanwhile, when K>2.5 is satisfied, the change is recognized on the above-mentioned irradiation surface as the flicker, and accordingly it is preferable to set the output voltage Vout of the direct-current power source 1 to be two and half times larger than the load voltage V1 of the LED module 4 or less. Additionally, in order to realize the step-down chopper operation, the lower limit of the output voltage Vout requires K>1, it is preferable to satisfy 1<K≤2.5. Moreover, considering the variation of the load voltage V1 due to a temperature characteristic of the LED and the like, it is more preferable to satisfy 1.2≤K≤2.5.

[0031] Next, Fig. 4 is a schematic circuit diagram showing another example of the LED lighting device according to the present embodiment. In the example shown in Fig. 1, a drive pulse of the drive pulse generation part 34 and an AND output of the PWM signal are outputted to the drive circuit 33 with use of the AND circuit 37; however, in the present example, a voltage superimposing the PWM signal on the voltage of the resistance R1 is compared with the reference voltage Vref, and the reset signal is outputted to the drive pulse generation part 34 in the case of exceeding the reference voltage Vref. Meanwhile, other configurations are the same as those of Fig. 1, and accordingly the same numerals are given to the same components to omit the explanations.

[0032] According to the present configuration, a signal of the reference voltage Vref or more is inputted to the comparator 35 when the PWM signal is Low, and thus the reset signal continues to be inputted to the drive pulse generation part 34. Accordingly, on this occasion, the drive pulse is not inputted to the drive circuit 33, and the switching element Q1 is kept to be off. On the other hand, when the PWM signal is High, the output of the drive pulse generation part 34 becomes High due to the inputting of the output signal from the starter 32 or the zero current detection circuit 31 to turn on the switching element Q1 via the drive circuit 33, in the same manner as that of the LED lighting device shown in Fig. 1. Then, when the load current I1 flowing to the switching element Q1 increases and the signal inputted to the comparator 35 via the resistance R2 becomes the reference voltage Vref or more, the comparator 35 outputs the reset signal, and accordingly the output of the drive pulse generation part 34 becomes Low to turn off the switching element Q1. Specifically, when the PWM signal is High, the switching element Q1 is controlled to be on and off due to the drive pulse from the drive pulse generation part 34 in the same manner as that of the LED lighting device shown in Fig. 1. In addition, according to the configuration, a universal IC for PFC (MC33262 manufactured by the ON Semiconductor Co., Ltd. and L6562 manufactured by STMicroelectronics Co., Ltd.) can be used as the control circuit part 3, and consequently the number of parts can be reduced.

[0033] Thus, according to the present embodiment, by setting the output voltage Vout of the direct-current power source 1 to be larger than the load voltage V1 of the LED module 4 and to be 2.5 times as large as the load voltage V1 or less, the off period Toff where the optical output does not vary due to the change of the duty ratio of the above-mentioned PWM signal can be shortened, and consequently the optical output can be smoothly changed in the sweeping of the PWM signal. In addition, by switching the switching element Q1 to be turned on in synchronization with detection timing of the zero current detection circuit 31, the on/off control of the switching element Q1 can be certainly performed. Moreover, an illumination fixture able to smoothly change the optical output in the sweeping of the PWM signal can be provided by using the LED lighting device according to the present embodiment.

[0034] Here, in the present embodiment, the switching element Q1 is controlled in the critical mode; however, the switching element Q1 may be controlled in a sequential mode for switching the switching element Q 1 to be turned on, for example, before the current I2 flowing to the inductor L1 in the turning-off of the switching element Q1 becomes zero (I2>0). Also in this case, by setting the output voltage Vout of the direct-current power source 1 to be larger than the load voltage V1 of the LED module 4 and to be 2.5 times as large as the load voltage V1 or less, the optical output can be smoothly changed in the sweeping of the PWM signal, and additionally the on/off control of the switching element Q1 can be certainly performed. Meanwhile, in the case where the switching element Q1 is controlled in a non-sequential mode (an operation mode having a period where the current I2 flowing to the inductor L1 becomes zero), the off-period of the switching element Q1 becomes long, and accordingly the operation mode is disadvantageous with respect to the above-mentioned critical mode and sequential mode, but has an advantage that the change of the optical output can be smooth.

(Second embodiment)

[0035] A second embodiment of an illumination fixture using the LED lighting device will be explained on the basis of Figs. 5 and 6. The present embodiment is different from the first embodiment in that the direct-current power source 1 includes an AC-DC converter and further the load voltage V1 of the LED module 4 is feed backed to the AC-DC converter. Meanwhile, other configurations are the same as those of the first embodiment, and accordingly explanations of the same components will be omitted by adding the same reference numerals.

[0036] The LED lighting device according to the present embodiment includes: the step-down chopper circuit part 2, the control circuit part 3, and a voltage detection part 6 for detecting the load voltage V1 of the LED module 4 and feed backing the load voltage V1 to the direct-current power source 1.

[0037] The direct-current power source 1 includes the AC-DC converter for converting an alternating-current output of a commercial alternating-current power source 5 into a direct-current voltage of a desired voltage value, and includes: an error amplifier 12 for comparing the load voltage V1 of the LED module 4 with the output voltage Vout and amplifying and outputting the error, and a control circuit 11 for controlling the switching element Q2 to be turned on and off in accordance with an output value of the error amplifier 12.

[0038] Here, in the present embodiment, the voltage detection part 6 detects the load voltage V1 of the LED module 4 and feed backs the load voltage V1 to the direct-current power source 1, and in the direct-current power source 1, the feedback controls is performed so that the output voltage Vout can be M times larger than the feed backed load voltage V1. Accordingly, in the same manner as that of the first embodiment, when $1<M\leq 2.5$ is set, the off period Toff where the optical output does not vary due to the change of the duty ratio of the PWM signal can be shortened, and consequently the optical output can be smoothly changed in the sweeping of the PWM signal. In addition, as in the present embodiment, when the load voltage V1 is feed backed to the direct-current power source 1, a relationship between the output voltage Vout of the direct-current power source 1 and the load voltage V1 of the LED module 4 can be retained to be constant even in the case where the load voltage V1 caries, and consequently, the optical output variation more close to a linear-shape with respect to the PWM signal can be realized. Meanwhile, the on-duty of the switching element Q1 is 1/M, and the more the M is close to 1, the more the illumination variation becomes smooth.

[0039] Meanwhile, in the case of using the AC-DC converter as in the present embodiment, ripples of 100Hz/120Hz appear in the output voltage Vout due to a capacity of an electrolytic capacitor C1 and the like, and thus the flicker of the optical output of the LED module 4 may occur due to interference between the ripples and a frequency of the PWM signal. In order to avoid the interference, it is preferable to set the frequency of the PWM signal to 600Hz or multiples of 600Hz, and consequently the interference of the ripples can be suppressed in both cases of 100Hz and 120Hz to allow obtaining substantially constant optical output where the flicker is suppressed.

[0040] In addition, Fig. 6 is a schematic circuit diagram showing another example of the LED lighting device according to the present embodiment, the illustrations of the AC-DC converter and the voltage detection part 6 in Fig. 5 are omitted. In the example shown in Fig. 6, an electrolytic capacitor C2 is connected in parallel with the LED module 4, the ripples of the current flowing to the LED module 4 can be reduced by the electrolytic capacitor C2, and consequently the flicker of the optical output can be suppressed. Moreover, the illumination fixture able to smoothly change the optical output in the sweeping of the PWM signal can be provided by using the LED lighting device according to the present embodiment.

[0041] Here, in the present embodiment, the direct-current power source 1 includes the AC-DC converter but may include a DC-DC converter. Additionally, in the present embodiment, the step-down chopper circuit part 2 is provided on a low-voltage side of the direct-current power source 1; however, the step-down chopper circuit part 2 may be provided on a high-voltage side of the direct-current power source 1. Moreover, in the above-mentioned first and second embodiments, the LED lighting device employing the LED as loads is explained as an example; however, the load is desired to be the solid light-emitting element, for example, may be an organic EL. Furthermore, in the above-mentioned first and second embodiments, the on/off of the switching element Q1 is controlled in accordance with the drive pulse in the on-period of the PWM signal (refer to Fig. 2); however, the on/off of the switching element Q1 may be controlled in accordance with the drive pulse in the off-period of the PWM signal. Meanwhile, in this case, it is required to set the length of the off-period of the PWM signal in accordance with the dimming level.

[Description of Reference Numerals]

[0042]

1	Direct-current power source
3	Control circuit part
4	LED module (Solid light-emitting element and loads)

34 Drive pulse generation part
D 1 Diode
L1 Inductor
Q 1 Switching element

Claims

1. A solid light-emitting element lighting device comprising: a series circuit of an inductor and a switching element that are connected between output terminals of a direct-current power source via a load; a diode for regenerating, during turning-off of the switching element, energy accumulated during turning-on of the switching element in the inductor to the load; and a control circuit part for controlling on and off of the switching element, wherein
the control circuit part includes a drive signal generation part for generating a drive signal whose pulse width varies in accordance with an amplitude of a load current, and controls the on and off of the switching element due to the drive signal in an on-period or an off-period of the PWM signal whose on-duty varies in accordance with a dimming level, the PWM signal being a lower frequency than the drive signal, and
an output voltage of the direct-current power source is set to be larger than the load voltage applied to the load and to be 2.5 times as large as the load voltage or less.

2. The solid light-emitting element lighting device according to claim 1, wherein
the control circuit part includes a zero current detection circuit for detection that a current flowing to the inductor becomes zero, and switches the switching element from being turned off to being turned on in synchronization with detection timing of the zero current detection circuit.

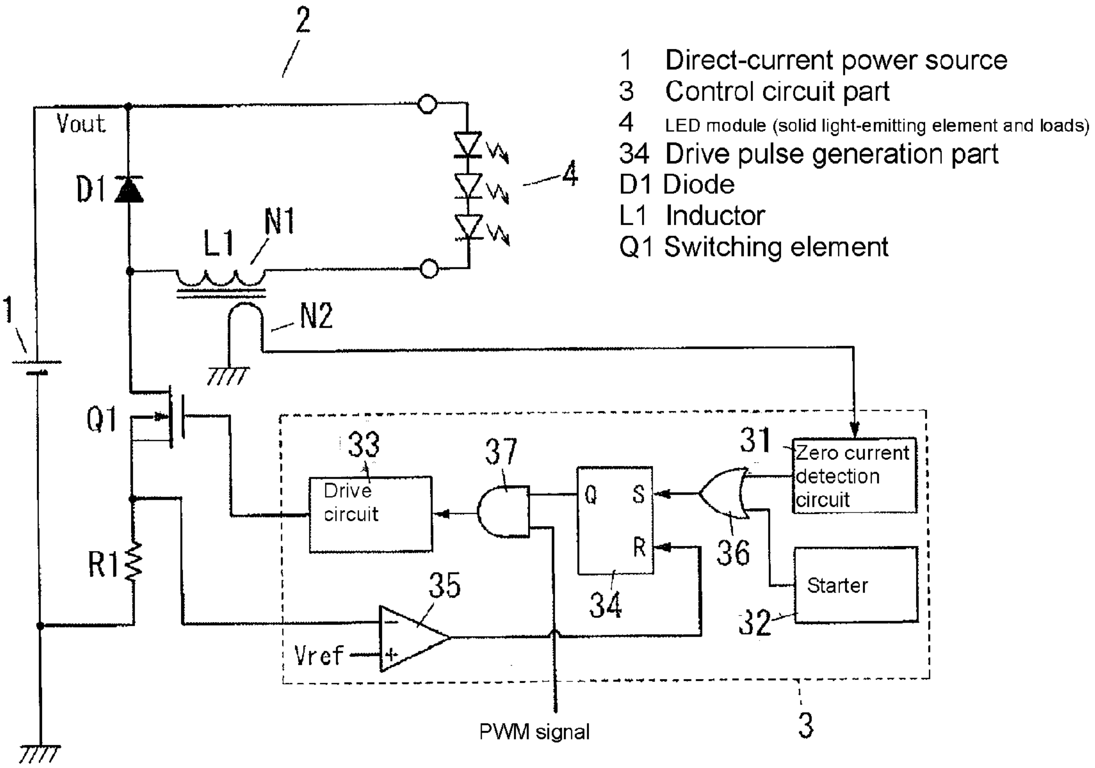
3. The solid light-emitting element lighting device according to claim 1, wherein
the control circuit part switches the switching element to be turned on before a current flowing to the inductor during the turning-off of the switching element becomes zero.

4. The solid light-emitting element lighting device according to any one of claims 1 to 3, wherein
the direct-current power source includes an AC-DC converter or a DC-DC converter to which a detection result of the load voltage is feed backed and that controls an output voltage to be a voltage proportional to the detection result, and includes a voltage detection part for detecting the load voltage and feed backing the load voltage to the direct-current power source.

5. The solid light-emitting element lighting device according to any one of claims 1 to 4, wherein
the direct-current power source includes the AC-DC converter, and a frequency of the PWM signal is set to 600Hz or multiples of 600Hz.

6. An illumination fixture comprising: the solid light-emitting element lighting device according to any one of claims 1 to 5; and a solid light-emitting element to which lighting power is supplied from the solid light-emitting element lighting device.

Figure 1



2
1 Direct-current power source
3 Control circuit part
4 LED module (solid light-emitting element and loads)
34 Drive pulse generation part
D1 Diode
L1 Inductor
Q1 Switching element
Vout
D1
L1
N1
N2
4
1
Q1
R1
33
Drive circuit
37
Q
S
R
31
Zero current detection circuit
36
Starter
32
34
35
Vref
PWM signal
3

Figure 2

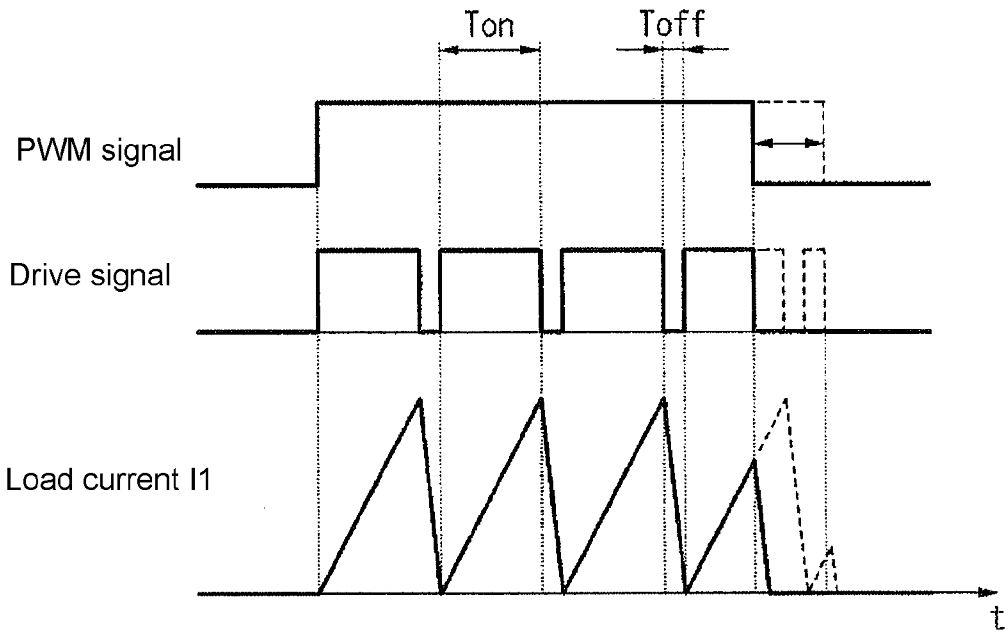


Figure 3

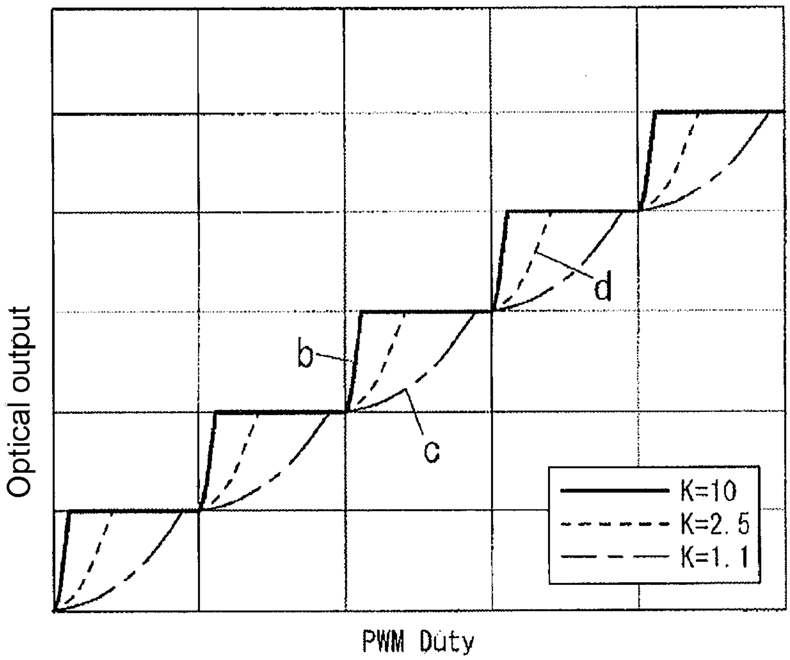


Figure 4

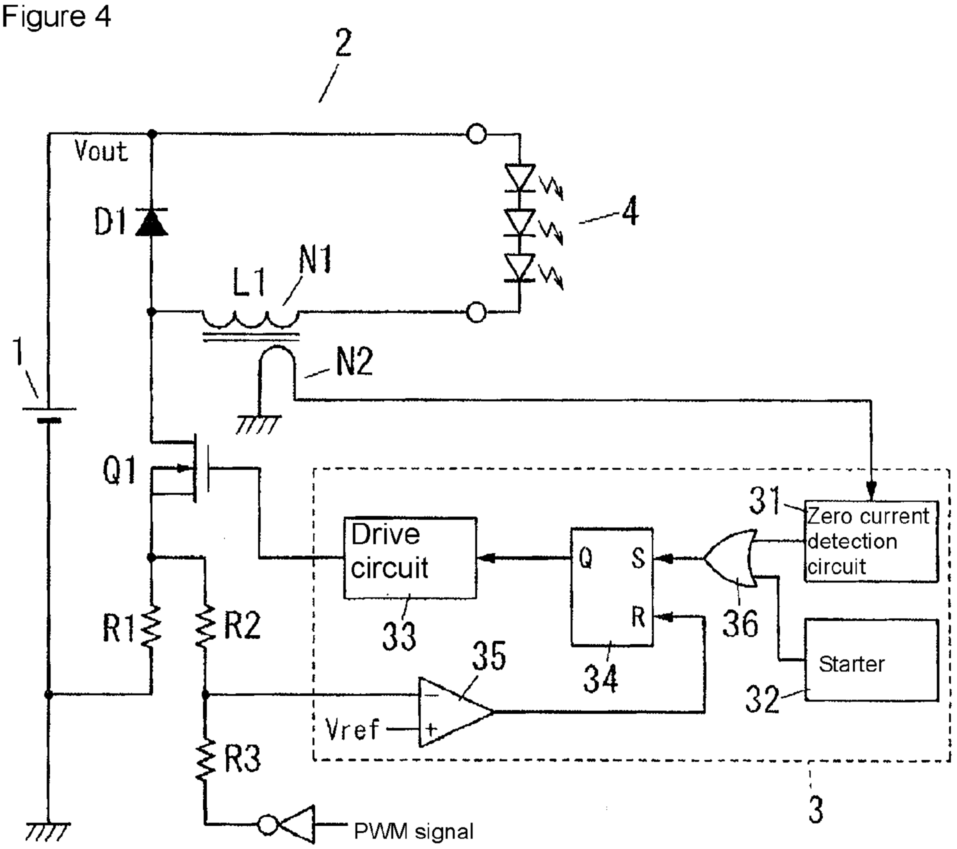
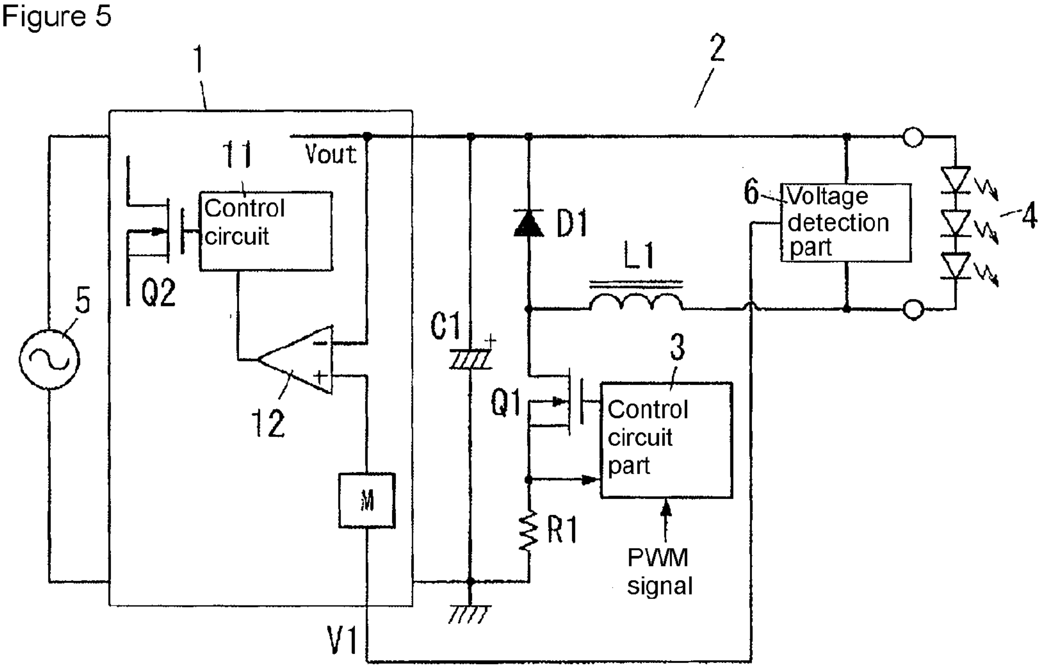


Figure 5



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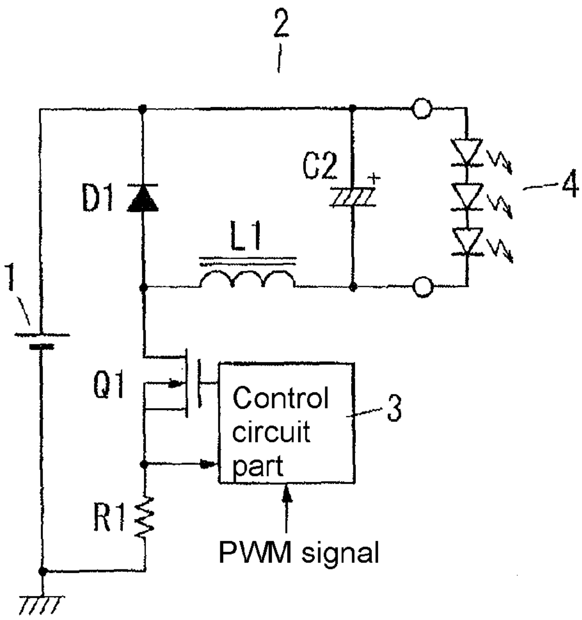
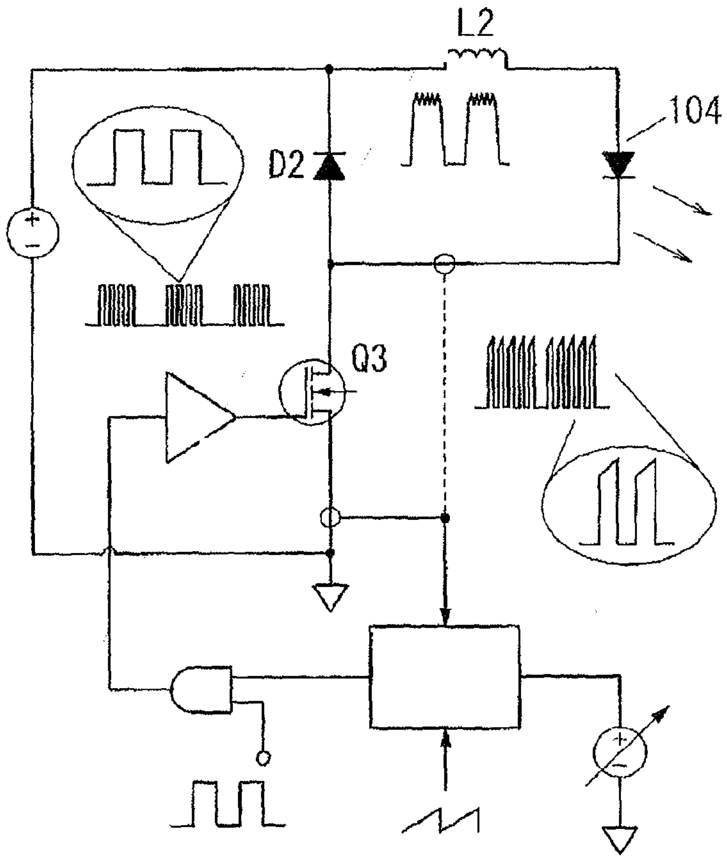


Figure 7



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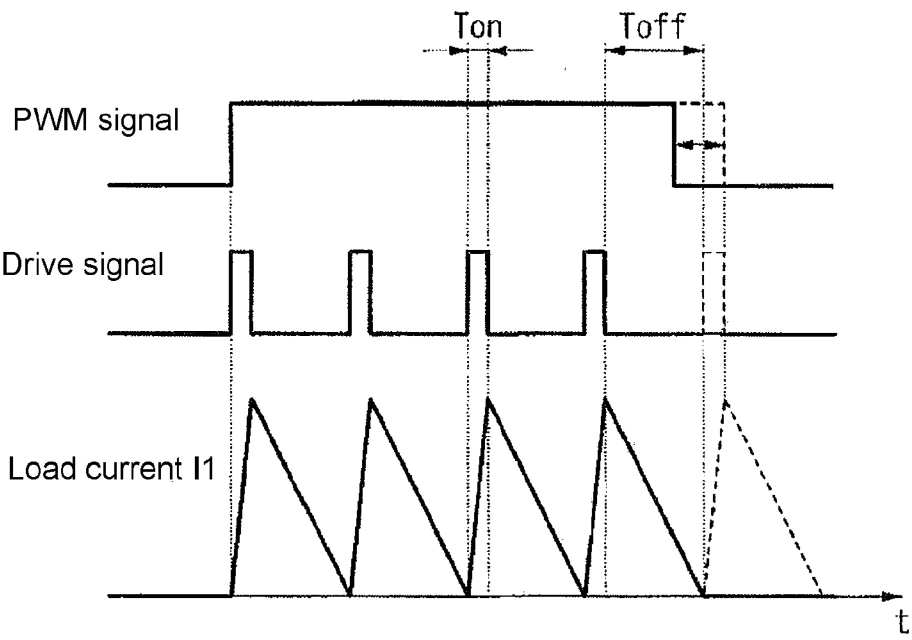
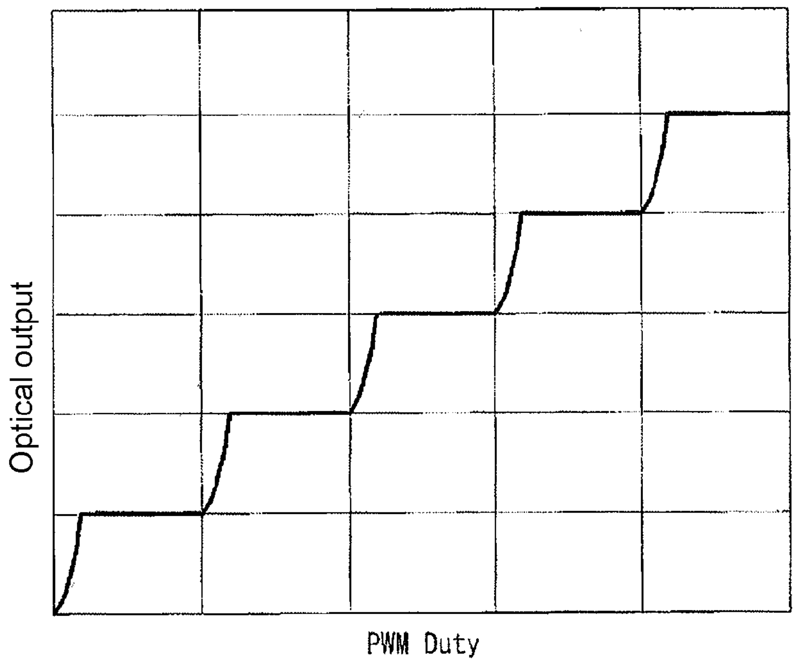


Figure 9



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EUROPEAN SEARCH REPORT

Application Number
EP 12 15 9970

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X Y	US 2003/085749 A1 (XU PENG [US] ET AL) 8 May 2003 (2003-05-08) * paragraph [0003] - paragraph [0031]; figures 1-4 *	1 2-6	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	18 September 2012	Henderson, Richard

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