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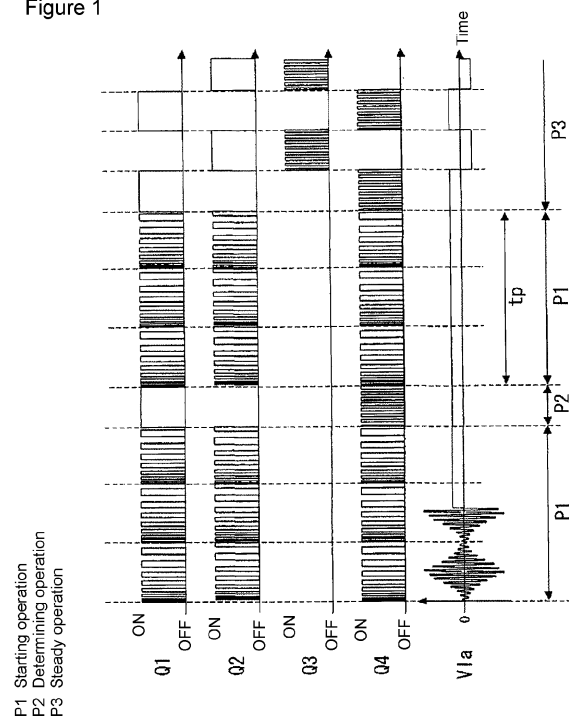
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(54) **High pressure discharge lamp lighting device and illumination fixture**

(57) [Object] To provide a high pressure discharge lamp lighting device and an illumination fixture that hardly go out immediately after start of a steady operation.

[Means for Settlement] In starting a high-pressure discharge lamp, a starting operation P1 of outputting a high voltage necessary for start of lighting to the high-pressure discharge lamp is performed and then, in a determining operation P2, a voltage V1a between both ends of the high-pressure discharge lamp is compared with a predetermined start determining voltage. When the voltage V1a between both ends of the high-pressure discharge lamp is smaller than the start determining voltage in the determining operation P2, the starting operation P1 is performed again and then, a steady operation of keeping lighting of the high-pressure discharge lamp is performed. Since a temperature of each electrode of the high-pressure discharge lamp can be increased in the starting operation P1 before a steady operation P3, as compared to the case the steady operation P3 is started immediately after the determining operation P2, the high-pressure discharge lamp hardly goes out immediately after the start of the steady operation P3.

Figure 1



## Description

[Technical Field]

**[0001]** The present invention relates to a high pressure discharge lamp lighting device and an illumination fixture.

[Background Art]

**[0002]** A high pressure discharge lamp lighting device for lighting a high-pressure discharge lamp using light emission by arc discharge in metal vapor has been conventionally proposed (refer to, for example, Patent Literature 1).

**[0003]** Fig. 12 illustrates an example of this type of high pressure discharge lamp lighting device.

**[0004]** This type of a high pressure discharge lamp lighting device includes a power converting circuit 1 that appropriately converts a DC voltage inputted from a DC power source E and outputs the converted voltage to a high-pressure discharge lamp DL, a lamp voltage detecting circuit 2 that detects an effective value of a voltage between both ends of the high-pressure discharge lamp DL (hereinafter referred to as a "lamp voltage") V1a and a control circuit 3 that controls the power converting circuit 1 according to the effective value of the lamp voltage V1a detected by the lamp voltage detecting part 2.

**[0005]** Describing in detail, a battery may be used as the DC power source E, and a well-known DC power circuit that converts AC power inputted from an AC power source (not shown) such as an external commercial power source into DC power having a predetermined voltage may be also used.

**[0006]** The power converting circuit 1 includes a full-bridge circuit formed by connecting two series circuits between output ends of the DC power source E in parallel with each other, the series circuits each formed of two elements of switching elements Q1 to Q4, an inductor L1 having one end connected to a connection point between the switching elements Q3, Q4 of one of the above-mentioned series circuits and the other end connected to one end (that is, one electrode) of the high-pressure discharge lamp DL, an autotransformer AT having one end connected to the other end (that is, the other electrode) of the high-pressure discharge lamp DL and the other end connected to a connection point between the switching elements Q1, Q2 of the other of the above-mentioned series circuits, a first capacitor C1 connected to a series circuit formed of the autotransformer AT and the high-pressure discharge lamp DL in parallel, and a second capacitor C2 having one end connected to a tap in the autotransformer AT (that is, between a series wiring and a shunt wiring) and the other end connected to an output end of the DC power source E on a low-voltage side. The above-mentioned switching elements Q1 to Q4 each have a parasitic diode and are connected so that a forward direction of the parasitic diode is opposite to a direction of the voltage of the DC power source E. A field

effect transistor, for example, can be used as each of the switching elements Q1 to Q4.

**[0007]** In the case where the lamp voltage V1a is a DC voltage in a period when the effective value of the lamp voltage V1a is detected as in a below-mentioned determining operation P2, the lamp voltage detecting part 2 may be formed using a voltage dividing resistor (not shown). The lamp voltage detecting part 2 may include a rectifying diode (not shown) or a smoothing capacitor (not shown) as necessity arises.

**[0008]** The control circuit 3 is formed of, for example, an integrated circuit called as a microcomputer and turns on/off each of the switching elements Q1 to Q4 of the power converting circuit 1, thereby controlling an output from the power converting circuit 1 to the high-pressure discharge lamp DL. The control circuit 3 described above can be realized according to well-known techniques, detailed illustration and description thereof are omitted.

**[0009]** When starting lighting of the high-pressure discharge lamp DL, the control circuit 3 first, as shown in Fig. 13, performs a starting operation P1 of controlling the power converting circuit 1 so as to output a high voltage necessary for starting lighting of the high-pressure discharge lamp DL to the high-pressure discharge lamp DL for a predetermined starting period. In the starting operation P1, the switching elements Q1, Q2, Q4 are turned on/off so that a pair of the high-voltage side switching element Q1 connected to the autotransformer AT and the low-voltage side switching element Q4 connected to the inductor L1, and the low-voltage side switching element Q2 connected to the autotransformer AT are alternately turned on while keeping the high-voltage side switching element Q3 connected to the inductor L1 in an OFF state. Further, in the starting operation P1, an operation of gradually changing a frequency for the above-mentioned turning-on/off from a high-frequency side to a low-frequency side of a resonance frequency of a resonance circuit formed of the shunt wiring of the autotransformer AT and the second capacitor C2 for a predetermined time is repeated a predetermined number of times (three times in this figure). In the above starting operation P1, a high voltage obtained by increasing a voltage due to resonance of the resonance circuit by the autotransformer AT is outputted to the high-pressure discharge lamp DL. The high voltage causes discharge in the high-pressure discharge lamp DL, thereby starting (that is, activating) lighting of the high-pressure discharge lamp DL.

**[0010]** Further, the control circuit 3 performs the determining operation P2 of comparing the lamp voltage V1a detected by the lamp voltage detecting part 2 with a predetermined start determining voltage in the state where the power converting circuit 1 is controlled so that a DC voltage is outputted to the high-pressure discharge lamp DL (the lamp voltage V1a becomes a DC voltage) after completion of the starting operation P1. Specifically describing the control of the power converting circuit 1 in the determining operation P2, while one pair formed of

diagonally-located switching elements Q2, Q3 in the switching elements Q1 to Q4 are kept in the OFF state and the switching element Q1 in the other pair formed of the switching elements Q1, Q4 in the switching elements Q1 to Q4 are kept in an ON state, the switching element Q4 is periodically turned on/off.

**[0011]** Here, the lamp voltage V1a in the determining operation P2 becomes the same level as an output voltage of the DC power source E when the high-pressure discharge lamp DL is not lighted, and the lamp voltage V1a while the high-pressure discharge lamp DL is lighted is lower than that while the high-pressure discharge lamp DL is not lighted. The start determining voltage is set so that the lamp voltage V1a is smaller than the start determining voltage when the high-pressure discharge lamp DL is lighted and the lamp voltage V1a becomes equal to or larger than the start determining voltage when the high-pressure discharge lamp DL is not lighted.

**[0012]** When the lamp voltage V1a is smaller than the start determining voltage, that is, it is determined that the high-pressure discharge lamp DL is lighted in the determining operation P2, the control circuit 3 starts a steady operation P3 of controlling the power converting circuit 1 so as to keep lighting of the high-pressure discharge lamp DL. In the steady operation P3, by performing a similar operation to the determining operation P2 while alternately switching the pair of switching elements Q1 to Q4 to be kept in the OFF state at a relatively low frequency (hereinafter referred to as a "steady frequency"), rectangular wave AC power having the steady frequency is outputted to the high-pressure discharge lamp DL.

**[0013]** Further, when the lamp voltage V1a is equal to or larger than the start determining voltage, that is, it is determined that the high-pressure discharge lamp DL is not lighted in the determining operation P2, as shown in Fig. 14, the control circuit performs a stopping operation P0 of stopping an input of power to the high-pressure discharge lamp DL by keeping all of the switching elements Q1 to Q4 of the power converting circuit 1 in the OFF state for a predetermined time and then, performs a series of operations from the starting operation P1 in the starting period to the determining operation P2 again.

[Conventional Technical Literature]

[Patent Literature]

**[0014]** [Patent Literature 1] JPT-2005-507554

[Disclosure of the Invention]

[Problems to be solved by the Invention]

**[0015]** Here, Figs. 15(a) (b) illustrate a measurement result of a change with time of a current flowing to the high-pressure discharge lamp DL (hereinafter referred to as a "lamp current") (that is, lamp current waveform) in the case of using HCI-TC/E70W/NDL manufactured

by OSRAM Corporation as the high-pressure discharge lamp DL. Fig. 15(a) illustrates the case where duration of the starting operation P1 is relatively long and a temperature of each electrode (not shown) of the high-pressure discharge lamp DL sufficiently rises at start of the steady operation P3, and Fig. 15(b) illustrates the case where duration of the starting operation P1 is relatively short and the temperature of each electrode of the high-pressure discharge lamp DL does not sufficiently rise at start of the steady operation P3.

**[0016]** When the temperature of each electrode of the high-pressure discharge lamp DL does not sufficiently rise at start of the steady operation P3, the high-pressure discharge lamp DL easily goes out immediately after start of the steady operation P3.

**[0017]** In consideration of the above-mentioned circumstances, the present invention intends to provide a high pressure discharge lamp lighting device and an illumination fixture that hardly cause going-out immediately after start of the steady operation.

[Means Adapted to solve the Problems]

**[0018]** According to a first aspect of the present invention, a power converting circuit that appropriately converts power inputted from outside and outputs the power to a high-pressure discharge lamp and a control circuit that controls the power converting circuit are provided. In starting lighting of the high-pressure discharge lamp, the control circuit continues a starting operation of controlling the power converting circuit so as to output a high voltage necessary for start of lighting of the high-pressure discharge lamp to the high-pressure discharge lamp for a predetermined starting period at least while the high-pressure discharge lamp is not lighted, and then, performs a determining operation of comparing an effective value of a voltage between both ends of the high-pressure discharge lamp with a predetermined start determining voltage; when an effective value of the voltage between both ends of the high-pressure discharge lamp is equal to or larger than the start determining voltage in a determining operation, performs the starting operation for the starting period and the determining operation again; and when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage in the determining operation, performs the starting operation again before starting a steady operation of controlling the power converting circuit so as to keep lighting of the high-pressure discharge lamp.

**[0019]** According to this aspect of the present invention, since the high-pressure discharge lamp can be lighted again even if the high-pressure discharge lamp goes out in the starting operation after the determining operation in which the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage and a temperature of each electrode of the high-pressure discharge lamp can

be increased in the starting operation, as compared to the case where the steady operation is started immediately after the determining operation, the high-pressure discharge lamp hardly goes out immediately after start of the steady operation.

**[0020]** According to a second aspect of the present invention, in the first aspect of the present invention, in the determining operation, the control circuit detects the voltage between both ends of the high-pressure discharge lamp while controlling the power converting circuit so as to output a DC voltage to the high-pressure discharge lamp.

**[0021]** According to a third aspect of the present invention, in the second aspect of the present invention, the control circuit reverses a direction of the voltage outputted to the high-pressure discharge lamp in the determining operation for each determining operation.

**[0022]** According to this aspect of the present invention, as compared to the case where the direction of the voltage outputted to the high-pressure discharge lamp is made constant in all determining operations, since a temperature difference between electrodes of the high-pressure discharge lamp is suppressed, the occurrence of half-discharge as a cause of going-out is prevented.

**[0023]** According to a fourth aspect of the present invention, in any of the first to third aspects of the present invention, in the starting operation, a frequency of the voltage outputted from the power converting circuit to the high-pressure discharge lamp is not changed at least while the high-pressure discharge lamp is lighted.

**[0024]** According to this aspect of the present invention, as compared to the case where, in the starting operation, the frequency of the voltage outputted from the power converting circuit to the high-pressure discharge lamp is changed while the high-pressure discharge lamp is lighted, going-out of the high-pressure discharge lamp can be prevented.

**[0025]** According to a fifth aspect of the present invention, in any of the first to fourth aspects of the present invention, when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage in the determining operation, the control circuit decreases duration of the starting operation performed before starting the steady operation as the effective value of the voltage between both ends of the high-pressure discharge lamp in the determining operation is lower.

**[0026]** According to this aspect of the present invention, when it is assumed that the effective value of the voltage between both ends of the high-pressure discharge lamp in the determining operation is lower and discharge in the high-pressure discharge lamp becomes more stable, the steady operation can be started more rapidly.

**[0027]** According to a sixth aspect of the present invention, in any of the first to fifth aspects of the present invention, the control circuit also compares the effective value of the voltage between both ends of the high-pres-

sure discharge lamp with a predetermined stability determining voltage that is lower than the start determining voltage in the determining operation, and immediately starts the steady operation without performing the starting operation again when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the stability determining voltage.

**[0028]** According to this aspect of the present invention, when it is assumed that the effective value of the voltage between both ends of the high-pressure discharge lamp in the determining operation is sufficiently low and discharge in the high-pressure discharge lamp becomes sufficiently stable, the steady operation can be started rapidly.

**[0029]** According to a seventh aspect of the present invention, a power converting circuit that appropriately converts power inputted from outside and outputs the power to a high-pressure discharge lamp, and a control circuit that controls the power converting circuit are provided. In starting lighting of the high-pressure discharge lamp, the control circuit continues a starting operation of controlling the power converting circuit so as to output a high voltage necessary for start of lighting of the high-pressure discharge lamp to the high-pressure discharge lamp for a predetermined starting period at least while the high-pressure discharge lamp is not lighted, and then, performs a determining operation of comparing an absolute value of a voltage between both ends of the high-pressure discharge lamp with a predetermined stability determining voltage in the state where the power converting circuit is controlled so as to output the DC voltage to the high-pressure discharge lamp; reverses a direction of the voltage outputted to the high-pressure discharge lamp in the determining operation for each determining operation; when the absolute value of the voltage between both ends of the high-pressure discharge lamp is equal to or larger than a stability determining voltage in at least one of a current determining operation and a previous determining operation, performs the starting operation for the starting period and the determining operation again; and when the absolute value of the voltage between both ends of the high-pressure discharge lamp is smaller than the stability determining voltage in both the current determining operation and the previous determining operation, starts a steady operation of controlling the power converting circuit so as to keep lighting of the high-pressure discharge lamp.

**[0030]** According to this aspect of the present invention, since the starting operation is inserted again at least once between the first determining operation in which the absolute value of the voltage between both ends of the high-pressure discharge lamp is smaller than the stability determining voltage and the steady operation, and a temperature of each electrode of the high-pressure discharge lamp can be increased in the second starting operation, as compared to the case where the steady operation is started immediately after the first determining operation, the high-pressure discharge lamp hardly goes

out immediately after start of the steady operation. Further, as compared to the case where the direction of the voltage outputted to the high-pressure discharge lamp is made constant in all determining operations, since a temperature difference between the electrodes of the high-pressure discharge lamp is suppressed, the occurrence of half-wave discharge as a cause of the going-out can be prevented.

**[0031]** According to an eighth aspect of the present invention, in the seventh aspect of the present invention, in the starting operation, the voltage outputted from the power converting circuit to the high-pressure discharge lamp while the high-pressure discharge lamp is lighted is a DC voltage, and the control circuit controls the power converting circuit so as to reverse the direction of the DC voltage outputted to the lighted high-pressure discharge lamp for each starting operation.

**[0032]** According to this aspect of the present invention, as compared to the case where the direction of the DC voltage outputted to the lighted high-pressure discharge lamp is made constant in all starting operations, since the temperature difference between the electrodes of the high-pressure discharge lamp is suppressed, an occurrence of half-wave discharge as the cause of the going-out can be prevented.

**[0033]** A ninth aspect of the invention includes the high pressure discharge lamp lighting device according to any of the first to eighth aspects of the present invention and a fixture main body holding the high pressure discharge lamp lighting device.

#### [Effect of the Invention]

**[0034]** According to the first aspect of the present invention, in the determining operation after the starting operation of controlling the power converting circuit so as to output the high voltage necessary for start of lighting of the high-pressure discharge lamp to the high-pressure discharge lamp is continued for the predetermined starting period at least while the high-pressure discharge lamp is not lighted, when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage, the control circuit performs the starting operation again before starting the steady operation of controlling the power converting circuit so as to keep lighting of the high-pressure discharge lamp. Therefore, since the high-pressure discharge lamp can be lighted again even if the high-pressure discharge lamp goes out in the starting operation after the determining operation in which the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage, and the temperature of each electrode of the high-pressure discharge lamp can be increased in the starting operation, as compared to the case where the steady operation is started immediately after the determining operation, the high-pressure discharge lamp hardly goes out immediately after start of the steady operation.

**[0035]** According to the third aspect of the present invention, since the control circuit reverses the direction of the voltage outputted to the high-pressure discharge lamp in the determining operation for each determining operation, as compared to the case where the direction of the voltage outputted to the high-pressure discharge lamp is made constant in all determining operations, a temperature difference between the electrodes of the high-pressure discharge lamp is suppressed. Therefore, the occurrence of half-wave discharge as the cause of the going-out can be prevented.

**[0036]** According to the fourth aspect of the present invention, since, in the starting operation, the frequency of the voltage outputted from the power converting circuit to the high-pressure discharge lamp is not changed at least while the high-pressure discharge lamp is lighted, as compared to the case where the frequency of a voltage outputted from the power converting circuit to the high-pressure discharge lamp is changed while the high-pressure discharge lamp is lighted, going-out of the high-pressure discharge lamp can be prevented.

**[0037]** According to the fifth aspect of the present invention, since when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage in the determining operation, the control circuit decreases duration of the starting operation performed before starting the steady operation as the effective value of the voltage between both ends of the high-pressure discharge lamp in the determining operation is lower, when it is assumed that the effective value of the voltage between both ends of the high-pressure discharge lamp in the determining operation is lower and discharge in the high-pressure discharge lamp becomes more stable, the steady operation can be started more rapidly.

**[0038]** According to the sixth aspect of the present invention, since, in the determining operation, the control circuit also compares the effective value of the voltage between both ends of the high-pressure discharge lamp with the predetermined stability determining voltage that is lower than the start determining voltage, and immediately starts the steady operation without performing the starting operation again when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the stability determining voltage, when it is assumed that the effective value of the voltage between both ends of the high-pressure discharge lamp in the determining operation is sufficiently low and discharge in the high-pressure discharge lamp becomes sufficiently stable, the steady operation can be started rapidly.

**[0039]** According to the seventh aspect of the present invention, in starting lighting of the high-pressure discharge lamp, the control circuit continues the starting operation of controlling the power converting circuit so as to output the high voltage necessary for start of lighting of the high-pressure discharge lamp to the high-pressure discharge lamp for the predetermined starting period at

least while the high-pressure discharge lamp is not light-  
ed, and then, performs the determining operation of com-  
paring the absolute value of the voltage between both  
ends of the high-pressure discharge lamp with the pre-  
determined stability determining voltage in the state  
where the power converting circuit is controlled so as to  
output the DC voltage to the high-pressure discharge  
lamp; reverses the direction of the voltage outputted to  
the high-pressure discharge lamp in the determining op-  
eration for each determining operation; when the abso-  
lute value of the voltage between both ends of the high-  
pressure discharge lamp is equal to or larger than the  
stability determining voltage in at least one of the current  
determining operation and the previous determining op-  
eration, performs the starting operation for the starting  
period and the determining operation again; and when  
the absolute value of the voltage between both ends of  
the high-pressure discharge lamp is smaller than the sta-  
bility determining voltage in both the current determining  
operation and the previous determining operation, starts  
the steady operation of controlling the power converting  
circuit so as to keep lighting of the high-pressure dis-  
charge lamp. Therefore, since the starting operation is  
inserted again at least once between the first determining  
operation in which the absolute value of the voltage be-  
tween both ends of the high-pressure discharge lamp is  
smaller than the stability determining voltage and the  
steady operation, and the temperature of each electrode  
of the high-pressure discharge lamp can be increased in  
the second starting operation, as compared to the case  
where the steady operation is started immediately after  
the first determining operation, the high-pressure dis-  
charge lamp hardly goes out immediately after start of  
the steady operation. Further, as compared to the case  
where the direction of the voltage outputted to the high-  
pressure discharge lamp is made constant in all deter-  
mining operations, the temperature difference between  
the electrodes of the high-pressure discharge lamp is  
suppressed, and the occurrence of half-wave discharge  
as the cause of the going-out can be prevented.

**[0040]** According to the eighth aspect of the present  
invention, since, in the starting operation, the voltage out-  
putted from the power converting circuit to the high-pres-  
sure discharge lamp while the high-pressure discharge  
lamp is lighted is the DC voltage, and the control circuit  
controls the power converting circuit so as to reverse the  
direction of the DC voltage outputted to the lighted high-  
pressure discharge lamp for each starting operation, as  
compared to the case where the direction of the DC volt-  
age outputted to the lighted high-pressure discharge  
lamp is made constant in all starting operations, the tem-  
perature difference between the electrodes of the high-  
pressure discharge lamp is suppressed. Therefore, the  
occurrence of half-wave discharge as the cause of the  
going-out can be prevented.

## [Brief Description of the Drawings]

### [0041]

[Fig. 11] Fig. 1 is an explanatory diagram illustrating  
operations in a first embodiment of the present in-  
vention and change with time of an ON/OFF state of  
each of switching elements Q1 to Q4 of a power con-  
verting circuit and a lamp voltage V1a.

[Fig. 2] Fig. 2 is a flow chart illustrating operations of  
a control circuit before a steady operation is per-  
formed in the first embodiment of the present inven-  
tion.

[Fig. 3] Fig. 3 is an explanatory diagram illustrating  
a relationship of a preparing period  $t_p$  and an abso-  
lute value  $|V1a|$  of the lamp voltage V1a in the first  
embodiment of the present invention.

[Fig. 4] Fig. 4 is an explanatory diagram illustrating  
change with time of the lamp voltage V1a in a mod-  
ification example of the first embodiment of the  
present invention.

[Fig. 5] Fig. 5 is a flow chart illustrating operations of  
a control circuit before a steady operation is per-  
formed in a second embodiment of the present in-  
vention.

[Fig. 6] Fig. 6 is an explanatory diagram illustrating  
operations in a third embodiment of the present in-  
vention and change with time of the ON/OFF state  
of each of the switching elements Q1 to Q4 of the  
power converting circuit and the lamp voltage V1a.

[Fig. 7] Fig. 7 is a flow chart illustrating operations of  
the control circuit before the steady operation is per-  
formed in the third embodiment of the present inven-  
tion.

[Fig. 8] Fig. 8 is an explanatory diagram illustrating  
operations in a comparison example of the third em-  
bodiment of the present invention, and change with  
time of the ON/OFF state of each of the switching  
elements Q1 to Q4 of the power converting circuit  
and the lamp voltage V1a.

[Fig. 9] Fig. 9 is a perspective view illustrating an  
example of an illumination fixture using the third em-  
bodiment of the present invention.

[Fig. 10] Fig. 10 is a perspective view illustrating an-  
other example of an illumination fixture using the  
third embodiment of the present invention.

[Fig. 11] Fig. 11 is a perspective view illustrating still  
another example of an illumination fixture using the  
third embodiment of the present invention.

[Fig. 12] Fig. 12 is a circuit block diagram illustrating  
an example of a high pressure discharge lamp light-  
ing device.

[Fig. 13] Fig. 13 is an explanatory diagram illustrating  
change with time of the ON/OFF state of each of the  
switching elements Q1 to Q4 of the power converting  
circuit and the lamp voltage V1a when the lamp volt-  
age V1a is smaller than a start determining voltage  
in a determining operation P2.

[Fig. 14] Fig. 14 is an explanatory diagram illustrating change with time of the ON/OFF state of each of the switching elements Q1 to Q4 of the power converting circuit and the lamp voltage V1a when the lamp voltage V1a is equal to or larger than the start determining voltage in the determining operation P2.

[Fig. 15] Figs. 15 (a)(b) each are an explanatory diagram illustrating a measurement result of a lamp current waveform, wherein Fig. 15 (a) illustrates the case where duration of a starting operation P1 is relatively long and a temperature of each electrode of the high-pressure discharge lamp sufficiently rises at start of a steady operation P3, and Fig. 15 (b) illustrates the case where duration of the starting operation P1 is relatively short and the temperature of each electrode of the high-pressure discharge lamp does not sufficiently rise at start of the steady operation P3.

[Best Mode for Carrying out the Invention]

**[0042]** Preferred embodiments for carrying out the present invention will be described below referring to figures.

**[0043]** Since below-mentioned embodiments and the conventional example shown in Figs. 12 to 14 have a common basic configuration, illustration and description of the common parts are omitted.

(First embodiment)

**[0044]** In the present embodiment, the control circuit 3, as shown in Fig. 2, starts its operation (S1), continues the starting operation P1 for a predetermined starting period (S2) and then, controls each of the switching elements Q1 to Q4 of the power converting circuit 1 so as to output a DC voltage to the high-pressure discharge lamp DL to start the determining operation P2 (S3), compares the lamp voltage V1a (strictly speaking, an effective value, that is, an absolute value  $|V1a|$  when the lamp voltage V1a is a DC voltage, and however, in the present embodiment, since a polarity of the lamp voltage V1a in the determining operation P2 is constant, the voltage is referred to as merely "lamp voltage V1a") detected by the lamp voltage detecting circuit 2 in the determining operation P2 with the start determining voltage V1 (S4), performs the stopping operation P0 of keeping each of the switching elements Q1 to Q4 of the power converting circuit 1 in an OFF state as in the operation described referring to Fig. 14 when the lamp voltage V1a is equal to or larger than the start determining voltage V1 (N at S4) (S5), and then, returns to the starting operation P1 at the step S2.

**[0045]** Although the above-mentioned operations are the same as those in the conventional example, the present embodiment is different from the conventional example in the following point. That is, when the lamp voltage V1a is smaller than the start determining voltage

V1 in the determining operation P2 (Y at S4), the control circuit 3 does not immediately start the steady operation P3, but, as shown in Fig. 1, performs the starting operation P1 again for a preparing period  $t_p$  corresponding to the lamp voltage V1a in the determining operation P2 (S6) and then, starts the steady operation P3 (S7). As shown in Fig. 3, as the lamp voltage V1a is lower, the preparing period  $t_p$  is decreased.

**[0046]** With the above-mentioned configuration, since the high-pressure discharge lamp DL can be lighted again even if the lamp DL goes out in the starting operation P1 after the determining operation P2, and a temperature of each electrode of the high-pressure discharge lamp DL can be increased in the starting operation P1, as compared to the case where the steady operation P3 is started immediately after the determining operation P2 as in the conventional example, the high-pressure discharge lamp DL hardly goes out immediately after start of the steady operation P3.

**[0047]** Further, since duration of the starting operation P1 before the steady operation P3 is decreased as the lamp voltage V1a is lower, when it is assumed that the lamp voltage V1a is lower and discharge in the high-pressure discharge lamp DL is more stable, the steady operation P3 can be started more rapidly.

**[0048]** When the starting operation P1 and the determining operation P2 are performed multiple times, a direction (polarity) of the lamp voltage V1a may be reversed for each determining operation P2. Reversal of the direction of the lamp voltage V1a can be performed, for example, by exchanging control of one pair of diagonally-located switching elements Q1, Q4 of the power converting circuit 1 with control of the other pair of diagonally-located switching element Q2, Q3. By adopting this configuration, it is possible to suppress a temperature difference between electrodes of the high-pressure discharge lamp DL and prevent an occurrence of half-wave discharge as a cause of going-out.

**[0049]** Details of the starting operation P1 are not limited to those in the conventional example and, as shown in Fig. 4, in the starting operation P1, the lamp voltage V1a may become an AC voltage having a frequency higher than the frequency in the steady operation P3. In an example in Fig. 4, an amplitude of the lamp voltage V1a decreases with start of lighting of the high-pressure discharge lamp DL in the starting operation P1. Both of the cases shown in Figs. 1 and 4, to prevent going-out of the high-pressure discharge lamp DL, it is desired that the starting operation P1 does not allow the frequency of the lamp voltage V1a to change at least while the high-pressure discharge lamp DL is lighted. Furthermore, to prevent going-out of the high-pressure discharge lamp DL in the starting operation P1, it is desired that the starting operation P1 allows power that is 25% of rated power of the high-pressure discharge lamp DL or more to be outputted to the lighted high-pressure discharge lamp DL.

(Second embodiment)

**[0050]** Since the present embodiment and the first embodiment have a common basic configuration, description of common parts is omitted.

**[0051]** In the present embodiment, in the determining operation P2, the control circuit 3, as shown in Fig. 5, compares the lamp voltage V1a with the start determining voltage V1 as well as a predetermined stability determining voltage V2 ( $<V1$ ) that is lower than the start determining voltage V1 (S8). Then, when the lamp voltage V1a is equal to or larger than the start determining voltage V1, as in the conventional example, after the stopping operation P0 (S5), the starting operation P1 and the determining operation P2 are performed again. When the lamp voltage V1a is smaller than the start determining voltage V1 and equal to or larger than the stability determining voltage V2 (Y at S4 and N at S8), the starting operation P1 is performed again (S6) as in the first embodiment, and then, the steady operation P3 is started (S7). Further, when the lamp voltage V1a is smaller than the stability determining voltage V2 (Y at S8), it is determined that the temperature of the electrodes of the high-pressure discharge lamp DL sufficiently rises and discharge in the high-pressure discharge lamp DL becomes stable, and the steady operation P3 is immediately started without performing the starting operation P1 (S7).

**[0052]** With the above-mentioned configuration, when the temperature of the electrodes of the high-pressure discharge lamp DL sufficiently rises and discharge in the high-pressure discharge lamp DL becomes stable in the determining operation P2, the steady operation P3 can be started more rapidly than the case in the first embodiment.

(Third embodiment)

**[0053]** Since the present embodiment and the second embodiment have a common basic configuration, description of common parts is omitted.

**[0054]** In the present embodiment, as shown in Figs. 6 and 7, a polarity (direction) of the DC voltage to be outputted to the high-pressure discharge lamp DL after lighting of the high-pressure discharge lamp DL in the starting operation P1 and the polarity of the DC voltage to be outputted to the high-pressure discharge lamp DL in the determining operation P2 are reversed for each starting operation P1 and each determining operation P2 (S9). Such polarity reversal can be performed, for example, by exchanging control of one pair of diagonally-located switching elements Q1, Q4 of the power converting circuit 1 with control of the other pair of diagonally-located switching element Q2, Q3. In the example in Fig. 6, such polarity reversal can be performed by exchanging control of the switching elements Q1, Q2 on an autotransformer AT side with each other and exchanging control of the switching elements Q3, Q4 on an inductor L1 side. The above-mentioned polarity reversal can suppress the tem-

perature difference between the electrodes of the high-pressure discharge lamp DL and prevent the occurrence of half-wave discharge as the cause of going-out, as compared to the case where the polarity of the DC voltage in the determining operation P2 is made constant and the polarity of the DC voltage in the starting operation P1 is made constant as shown in Fig. 8.

**[0055]** In the present embodiment, when the absolute value  $|V1a|$  of the lamp voltage V1a is equal to or larger than the stability determining voltage V2, the control circuit 3 does not start the steady operation P3 even when the absolute value  $|V1a|$  of the lamp voltage V1a is smaller than the start determining voltage V1. That is, whether or not the absolute value  $|V1a|$  of the lamp voltage V1a is smaller than the start determining voltage V1 in the determining operation P2 has an effect on only whether or not the stopping operation P0 is performed (S5) before the next starting operation P1 is performed (S2).

**[0056]** Further, in the determining operation P2, the control circuit 3 determines whether or not the absolute value  $|V1a|$  of the lamp voltage V1a is smaller than the stability determining voltage V2 in the previous determining operation P2 before the starting operation P1 (S10) and starts the steady operation (S7) only when the absolute value  $|V1a|$  of the lamp voltage V1a is smaller than the stability determining voltage V2 both in the previous time and this time (that is, consecutive twice) (Y at S4, S8 and S10).

**[0057]** In other cases (N at S4, S8 or S10), the polarity is reversed as described above (S9) and the starting operation P1 is started again (S2). Specifically, when the absolute value  $|V1a|$  of the lamp voltage V1a is equal to or larger than the start determining voltage V1 (N at S4), the stopping operation P0 is inserted before restart of the starting operation P1 (S5).

**[0058]** With the above-mentioned configuration, since the starting operation P1 is inserted again between the first determining operation P2 in which the absolute value  $|V1a|$  of the lamp voltage V1a is smaller than the stability determining voltage V2 (the first determining operation P2 in Fig. 6) and the steady operation P3 at least once, and the temperature of each electrode of the high-pressure discharge lamp DL can be increased in the second starting operation P1, the high-pressure discharge lamp DL hardly goes out immediately after start of the steady operation P3 as compared to the case where the steady operation P3 is started immediately after the first determining operation P2.

**[0059]** The above-mentioned various high pressure discharge lamp lighting devices can be used in illumination fixtures 5 as shown in Fig. 9 to Fig. 11, respectively. The illumination fixtures 5 in Fig. 9 to Fig. 11 each include the power converting circuit 1, a fixture main body 51 that stores and holds the lamp voltage detecting circuit 2 and the control circuit 3 and a light body 52 that holds the high-pressure discharge lamp DL. The illumination fixture 5 in Fig. 9 and the illumination fixture 5 in Fig. 10 each include an electric supply line 53 that electrically

connects the power converting circuit 1 to the high-pressure discharge lamp DL. Since the above-mentioned various illumination fixtures 5 can be realized according to well-known techniques, detailed description thereof is omitted.

[Description of Reference Numerals]

#### [0060]

- 1 Power converting circuit
- 3 Control circuit
- 5 Illumination fixture
- 51 Fixture main body
- DL High-pressure discharge lamp
- P1 Starting operation
- P2 Determining operation
- P3 Steady operation

#### Claims

1. A high pressure discharge lamp lighting device comprising:

a power converting circuit that appropriately converts power inputted from outside and outputs the power to a high-pressure discharge lamp; and  
a control circuit that controls the power converting circuit, wherein:

in starting lighting of the high-pressure discharge lamp, the control circuit continues a starting operation of controlling the power converting circuit so as to output a high voltage necessary for start of lighting of the high-pressure discharge lamp to the high-pressure discharge lamp for a predetermined starting period at least while the high-pressure discharge lamp is not lighted, and then, performs a determining operation of comparing an effective value of a voltage between both ends of the high-pressure discharge lamp with a predetermined start determining voltage;  
performs the starting operation for the starting period and the determining operation again when the effective value of the voltage between both ends of the high-pressure discharge lamp is equal to or larger than the

start determining voltage in the determining operation; and  
performs the starting operation again before starting a steady operation of controlling the power converting circuit so as to keep lighting of the high-pressure discharge lamp when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage in the determining operation.

2. The high pressure discharge lamp lighting device according to claim 1, wherein, in the determining operation, the control circuit detects the voltage between both ends of the high-pressure discharge lamp while controlling the power converting circuit so as to output a DC voltage to the high-pressure discharge lamp.
3. The high pressure discharge lamp lighting device according to claim 2, wherein the control circuit reverses a direction of the voltage outputted to the high-pressure discharge lamp in the determining operation for each determining operation.
4. The high pressure discharge lamp lighting device according to any one of claims 1 to 3, wherein in the starting operation, a frequency of the voltage outputted from the power converting circuit to the high-pressure discharge lamp is not changed at least while the high-pressure discharge lamp is lighted.
5. The high pressure discharge lamp lighting device according to any one of claims 1 to 4, wherein, when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the start determining voltage in the determining operation, the control circuit decreases duration of the starting operation performed before starting the steady operation as the effective value of the voltage between both ends of the high-pressure discharge lamp in the determining operation is lower.
6. The high pressure discharge lamp lighting device according to any one of claims 1 to 5, wherein the control circuit also compares the effective value of the voltage between both ends of the high-pressure discharge lamp with a predetermined stability determining voltage that is lower than the start determining voltage in the determining operation, and immediately starts the steady operation without performing the starting operation again when the effective value of the voltage between both ends of the high-pressure discharge lamp is smaller than the stability determining voltage.
7. A high pressure discharge lamp lighting device comprising:

a power converting circuit that appropriately converts power inputted from outside and outputs the power to a high-pressure discharge lamp; and

a control circuit that controls the power converting circuit, wherein:

in starting lighting of the high-pressure discharge lamp, the control circuit continues a starting operation of controlling the power converting circuit so as to output a high voltage necessary for start of lighting of the high-pressure discharge lamp to the high-pressure discharge lamp for a predetermined starting period at least while the high-pressure discharge lamp is not lighted, and then, performs a determining operation of comparing an absolute value of a voltage between both ends of the high-pressure discharge lamp with a predetermined stability determining voltage in the state where the power converting circuit is controlled so as to output the DC voltage to the high-pressure discharge lamp;

reverses a direction of the voltage outputted to the high-pressure discharge lamp in the determining operation for each determining operation;

performs the starting operation for the starting period and the determining operation again when the absolute value of the voltage between both ends of the high-pressure discharge lamp is equal to or larger than the stability determining voltage in at least one of the current determining operation and the previous determining operation; and

starts a steady operation of controlling the power converting circuit so as to keep lighting of the high-pressure discharge lamp when the absolute value of the voltage between both ends of the high-pressure discharge lamp is smaller than the stability determining voltage in both the current determining operation and the previous determining operation.

discharge lamp lighting device according to any one of claims 1 to 8 and a fixture main body holding the high pressure discharge lamp lighting device.

8. The high pressure discharge lamp lighting device according to claim 7, wherein in the starting operation, the voltage outputted from the power converting circuit to the high-pressure discharge lamp while the high-pressure discharge lamp is lighted is a DC voltage, and the control circuit controls the power converting circuit so as to reverse the direction of the DC voltage outputted to the lighted high-pressure discharge lamp for each starting operation.

9. An illumination fixture comprising the high pressure

Figure 1

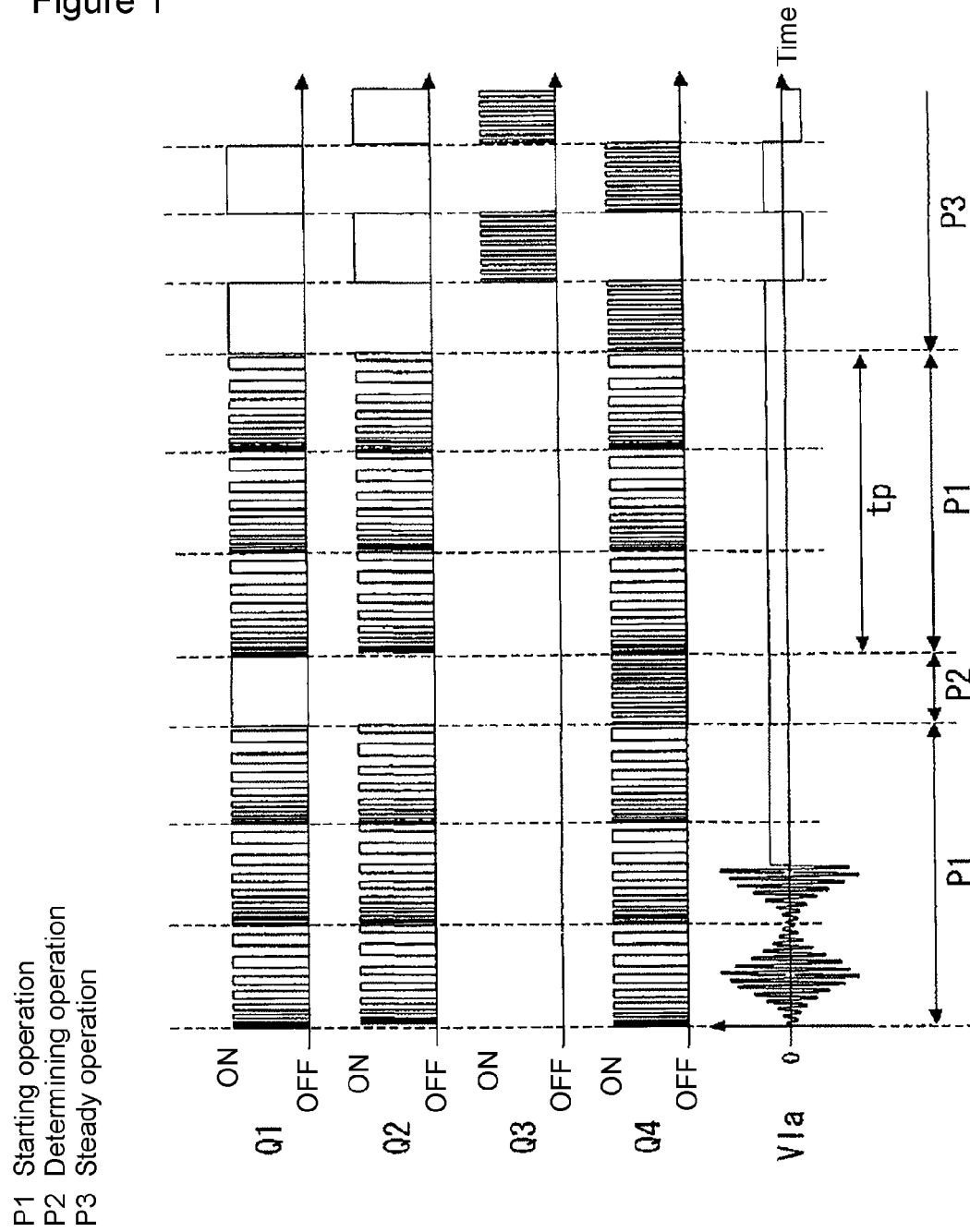


Figure 2

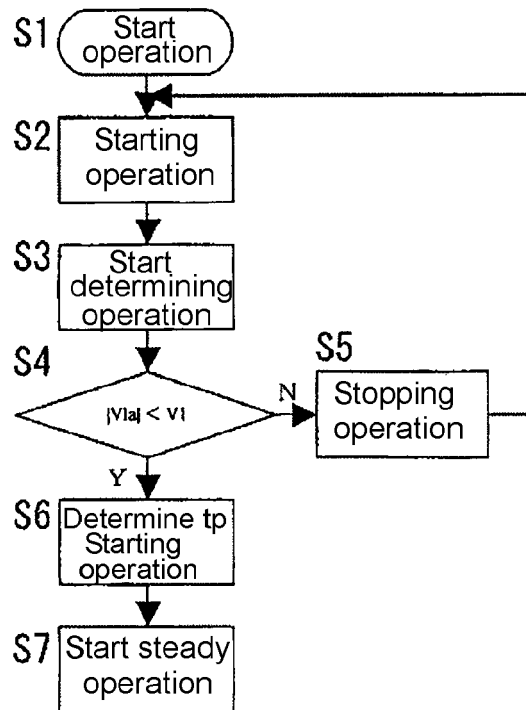


Figure 3

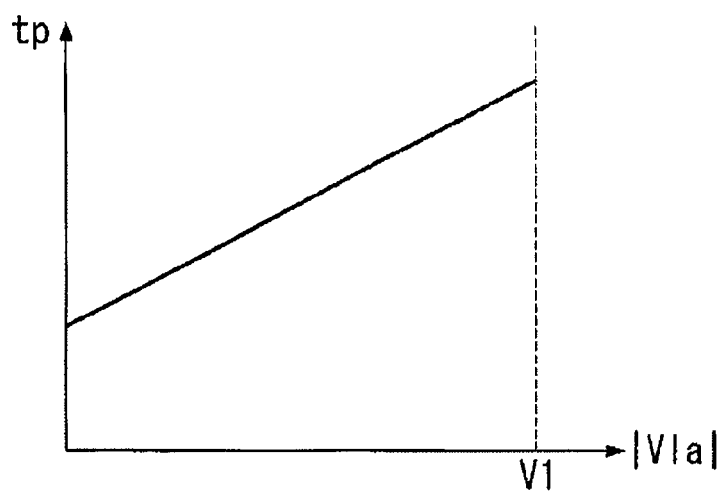


Figure 4

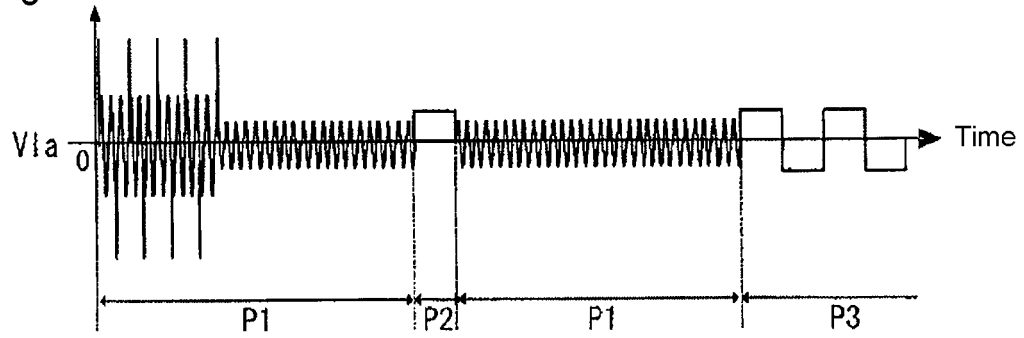


Figure 5

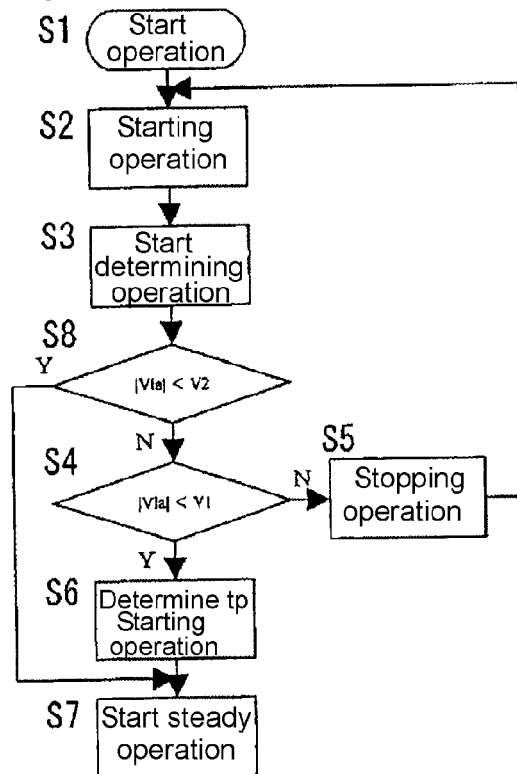


Figure 6

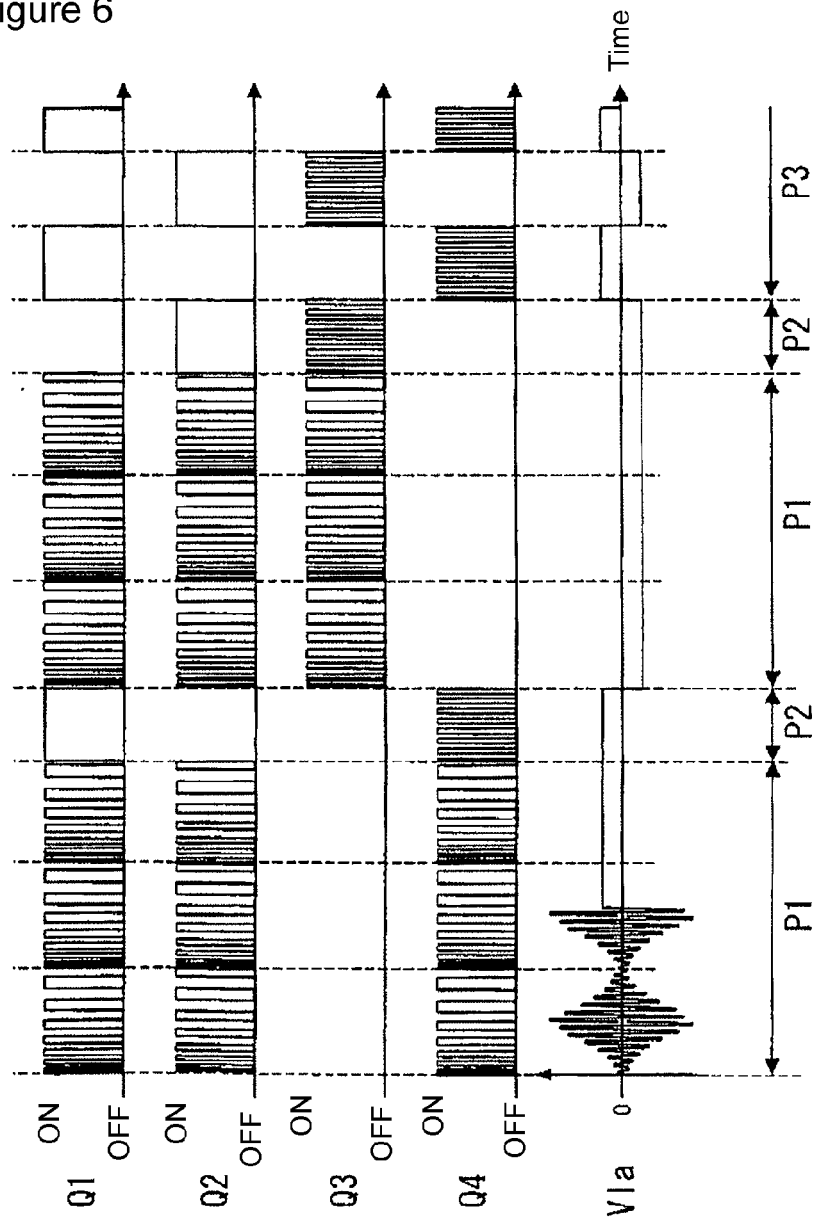


Figure 7

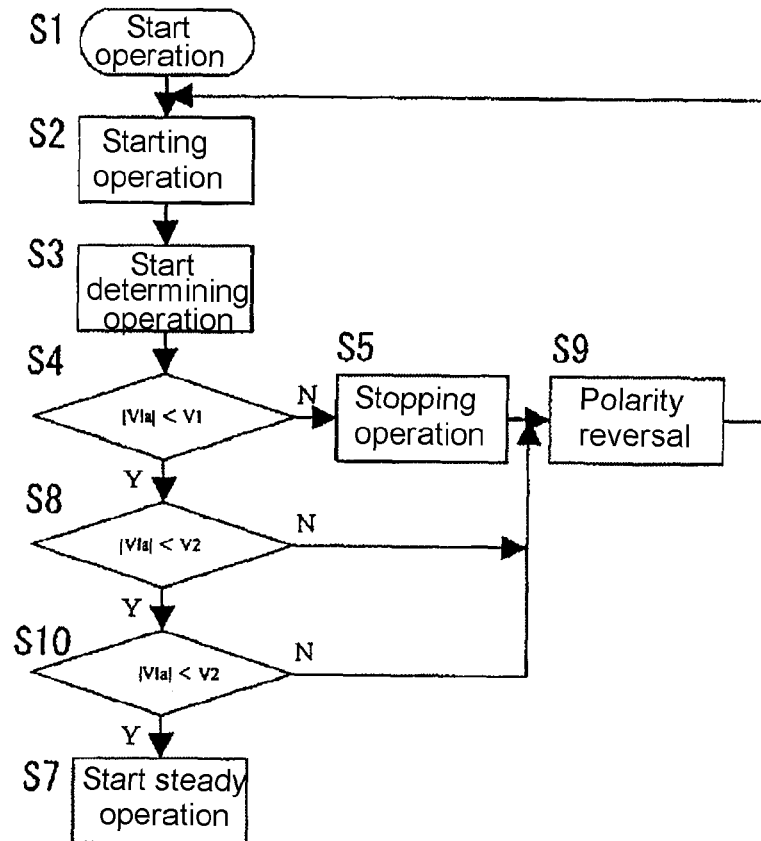


Figure 8

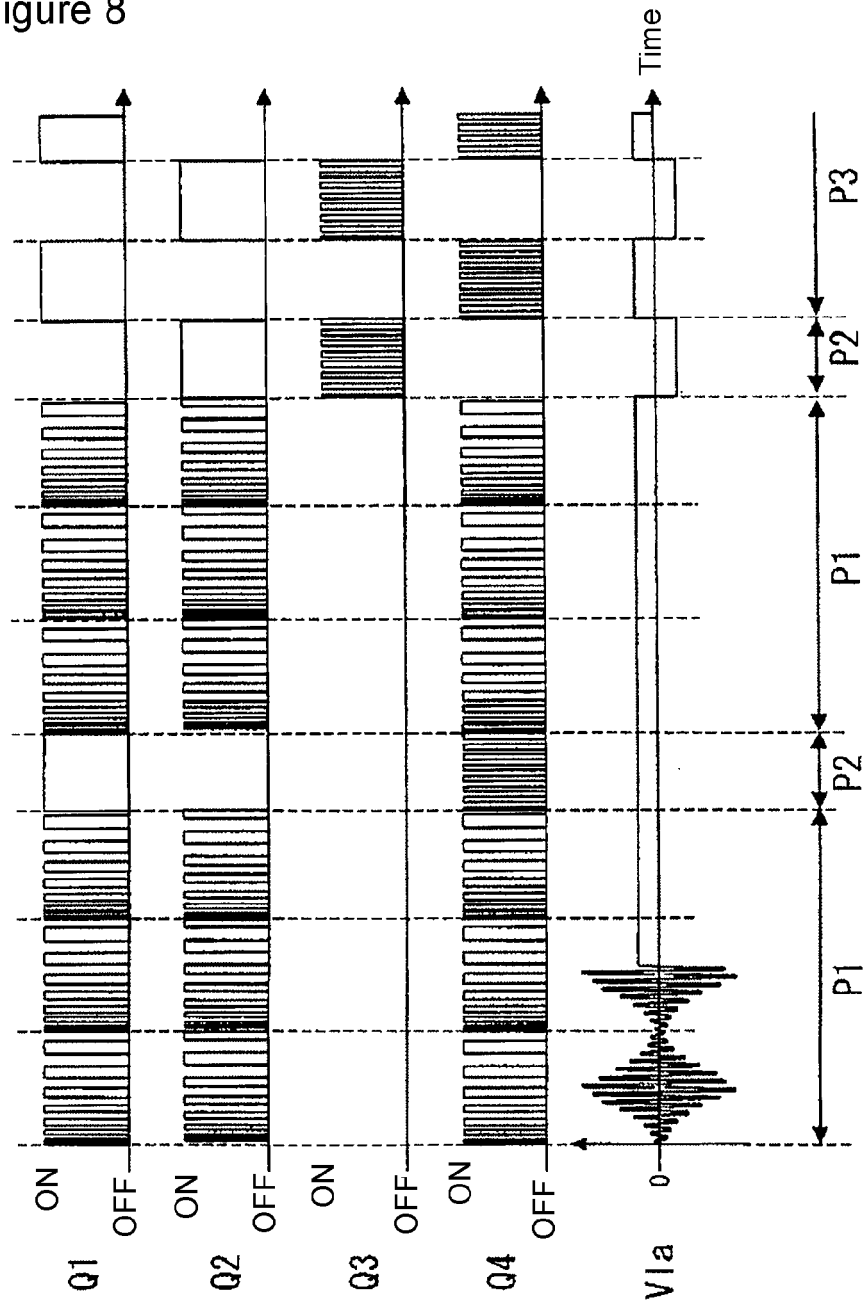


Figure 9

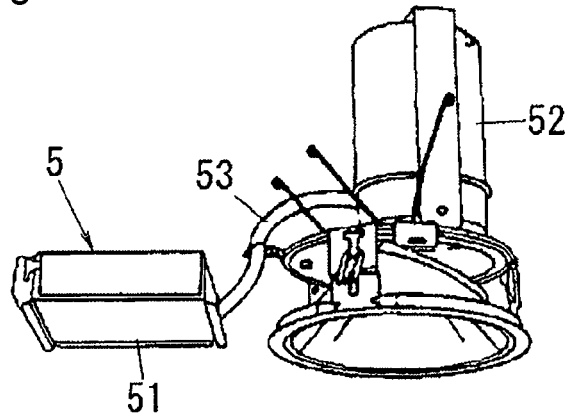


Figure 10

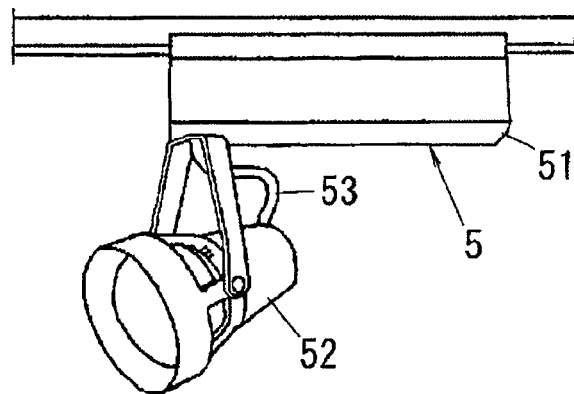


Figure 11

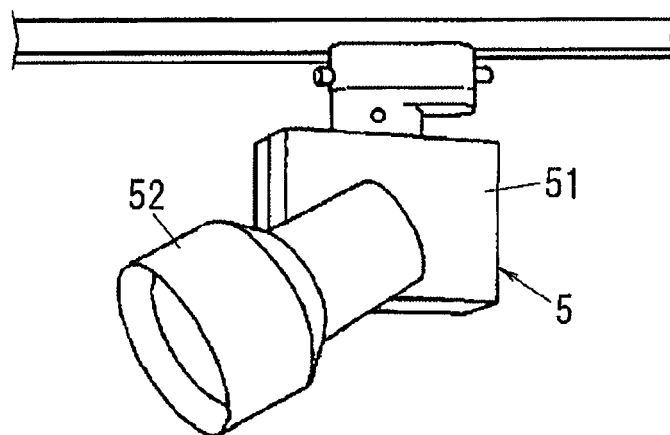


Figure 12

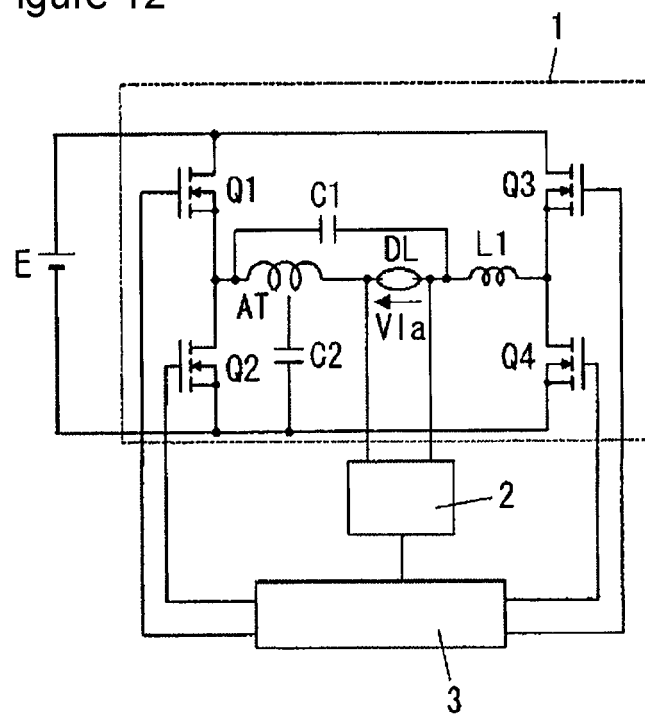


Figure 13

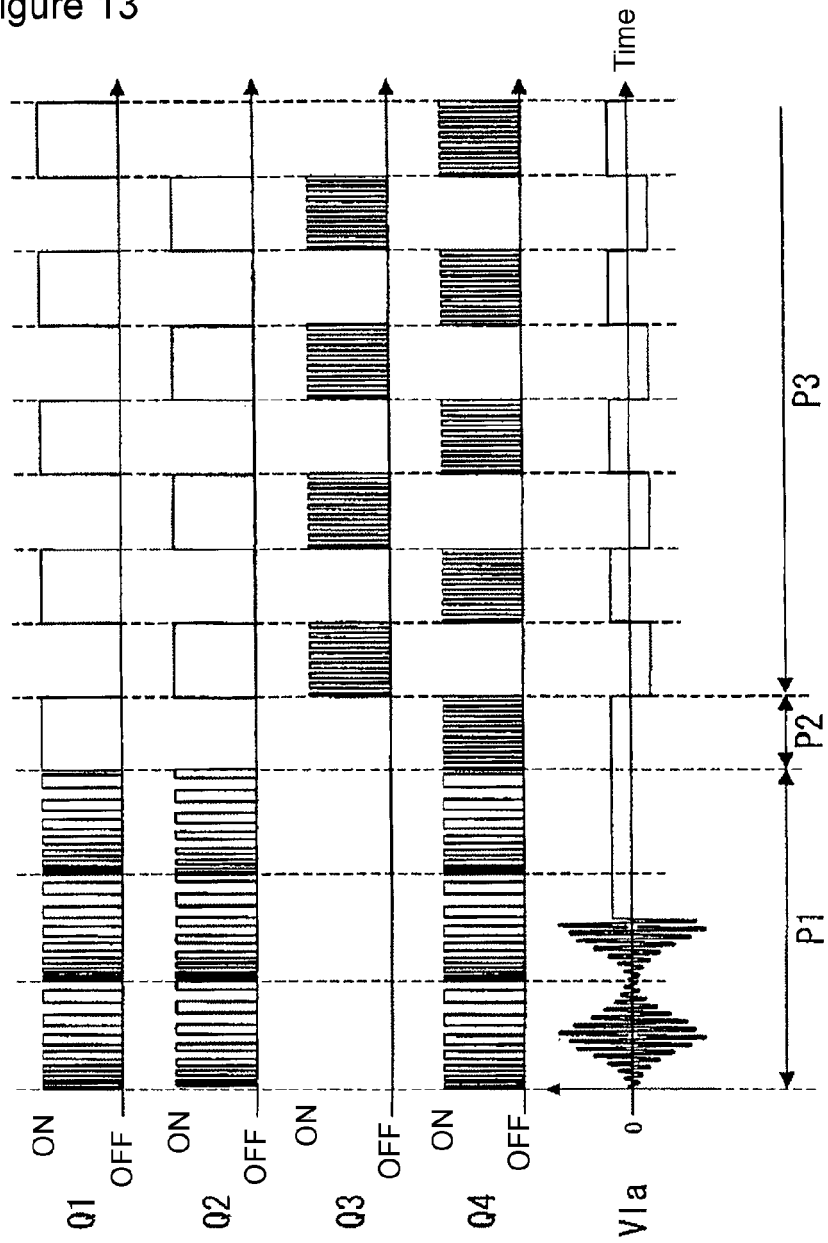


Figure 14

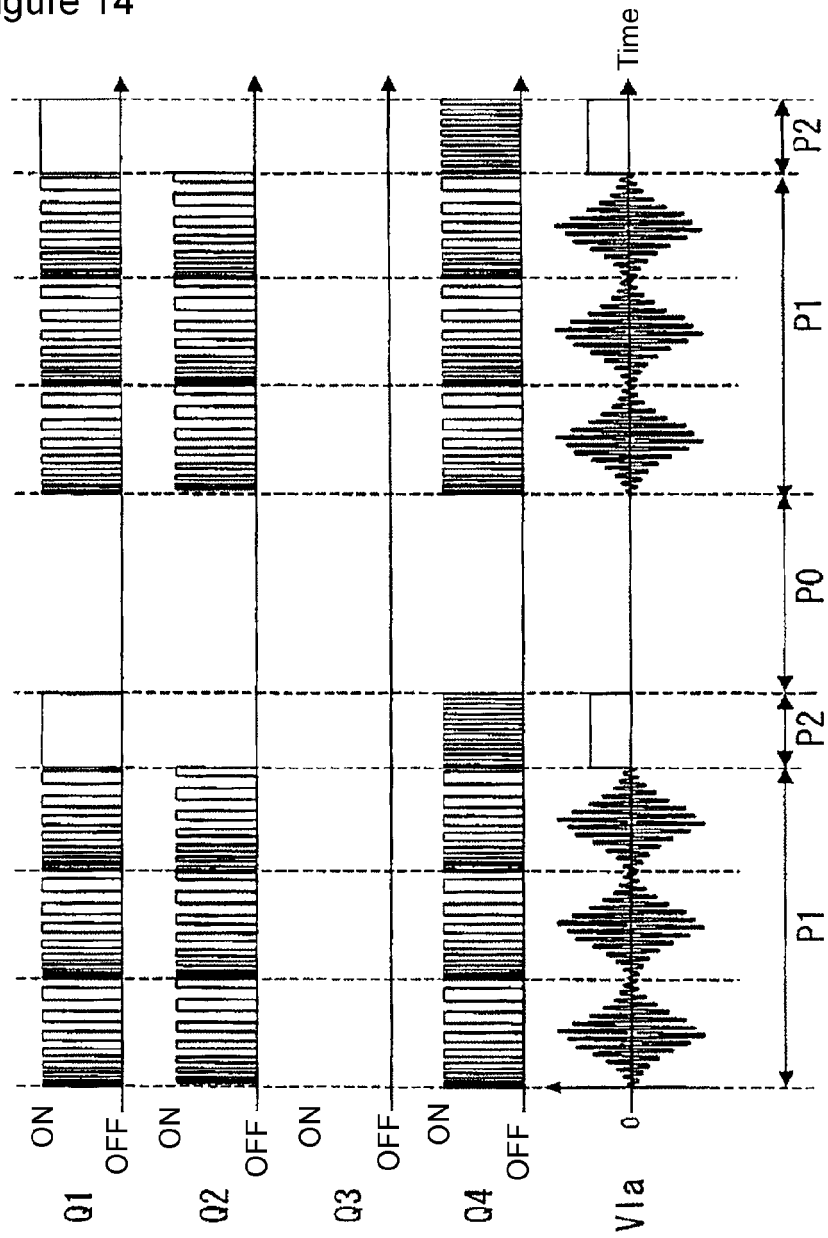


Figure 15

