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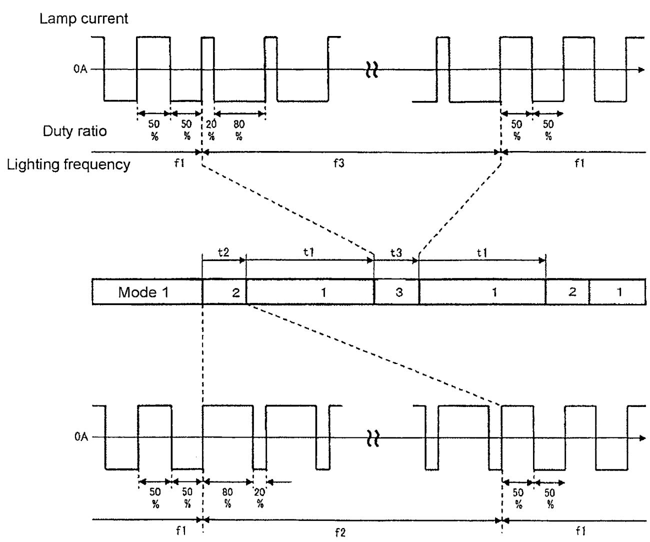
(54) High pressure discharge lamp lighting device and image display device

(57) [Object] To provide a high pressure discharge lamp lighting device which can reduce flickering of a high-pressure discharge lamp with a relatively simple control.

[Means for Settlement] Upon start of lighting of a high-pressure discharge lamp, after the high-pressure discharge lamp reaches a substantially stable state or reaches a predetermined lamp voltage, the high-pressure discharge lamp is lighted in at least three lighting modes with a predetermined average power put into the high-pressure discharge lamp, and in the lighting modes, a period of a positive polarity is nearly equal to a period of a negative polarity in a first mode, a period of a positive polarity is longer than a period of a negative polarity in a second mode, and a period of a positive polarity is shorter than a period of a negative polarity in a third mode. Lighting frequencies in the second mode and the third mode are equal to or less than a lighting frequency in the first mode, each of periods t1, t2, t3 in the modes is at least one cycle, at least one first mode, and at least one second mode and at least one third mode are collectively defined as one set and the one set is repeated.

Fig. 1



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Description

[Field of the Invention]

[0001] The present invention relates to a high pressure discharge lamp lighting device which lights a high-intensity high-pressure discharge lamp (HID lamp) such as a high-pressure mercury lamp and a metal halide lamp, and an image display device using the high pressure discharge lamp lighting device.

[Background Art]

[0002] In recent years, a projection-type projector using a liquid crystal device and a projection-type DLP (registered trademark of Texas Instruments Incorporated.) projectors using DMD (registered trademark of Texas Instruments Incorporated.) as a reflection image display element have been reduced in flickering of a lamp according to a method of superimposing a pulse current on a lamp current as disclosed in J Japanese Unexamined Patent Publication No. 1998-501919 and Japanese Unexamined Patent Publication No. 2001-244088 or a method of deforming waveform of the lamp current by superimposing triangular waveform on the lamp current as disclosed in Japanese Unexamined Patent Application Publication No. 2004-281381.

[0003] In the projection-type projector using the liquid crystal device, to improve contrast, a liquid crystal device employing a normally white mode has been changed to a liquid crystal device employing a normally black mode. The normally white mode is a mode in which a screen is black in a voltage application state and the normally black mode is a mode in which screen is white in a voltage application state.

[0004] A defect has recently appeared that white bars (horizontal bright lines) occur on both projection planes in the horizontal direction. Although the cause of the defect has not been clarified in detail, the defect is supposedly generated because a transistor of a driver is turned on due to photo leak of the liquid crystal device to the driver. When a method of superimposing the pulse current on a lamp current or the method of superimposing the triangular waveform on the lamp current is employed, a larger lamp current than normal is put into, resulting in that an optical output instantaneously increases and a photo leak is likely to occur, causing the above-mentioned defect. The aforementioned lighting methods are unsuitable for the projection-type projectors using the liquid crystal device.

[0005] Thus, to reduce flickering of the high pressure discharge lamp, at least projection-type projectors using the liquid crystal device require methods other than the method of superimposing the pulse current and the like on the lamp current. As such methods, a method of introducing a low frequency into a normal lighting frequency for a predetermined period as disclosed in Patent Document 1 (Japanese Unexamined Patent Publication No. 2006-59790) and a method of performing refresh lighting mode (lighting a lamp with a lighting frequency which is lower than the normal lighting frequency) upon input of a refresh signal as disclosed in Patent Document 2 (Japanese Unexamined Patent Publication No. 2008-177002) have been proposed.

[0006] Describing in more detail, flickering of the high-pressure discharge lamp is caused in the following manner: when the high-pressure discharge lamp is used for a long time, as life progresses, the shape of the electrode becomes rougher and a plurality of protrusions are generated; and at polarity inversion of a current put into the high-pressure discharge lamp, a bright point of an arc moves between the generated plurality of protrusions on an irregular basis. Thus, as a countermeasure, a frequency for forming protrusions on a front end of the electrode is selected as a normal lighting frequency to light the high-pressure discharge lamp and the high-pressure discharge lamp is lighted with a frequency which is lower than the normal lighting frequency on a regular basis. The lower frequency is selected as a lighting frequency which raises the temperature of the electrode surface and melts excessive protrusions so as not to generate a plurality of protrusions around the protrusions initially generated on a front end of the electrode.

[Patent Document 1] Japanese Unexamined Patent Publication No. 2006-59790
[Patent Document 2] Japanese Unexamined Patent Publication No.2008-177002
[Patent Document 3] Japanese Translation of PCT No. 10-501919
[Patent Document 4] Japanese Unexamined Patent Publication No. 2001-244088
[Patent Document 5] Japanese Unexamined Patent Publication No. 2004-281381

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0007] When a frequency which is lower than a normal lighting frequency is introduced as disclosed in Patent Document 1 and Patent Document 2, an optical output per unit time in a period of the lower lighting frequency becomes larger than that in a period of the normal lighting frequency. The reason is as follows: at polarity inversion of a current put into the high-pressure discharge lamp, since the polarity of the current is inverted through zero crossing with inclination, the optical output decreases in a polarity switching period and the optical output per unit time varies depending on a polarity inverting frequency. Accordingly, flickering due to variation in the lighting frequencies may occur. Furthermore, at a time point of the current polarity being switched, since power put into the high-pressure discharge lamp also decreases, an average power value varies depending on the number of times of polarity inversion. In the case where a variation range of the average power values is problematic, it is need to design a power control amount so that the average power value at the normal lighting frequency is nearly equal to the average power value at the low frequency.

[0008] When the frequency which is lower than the normal lighting frequency is introduced for lighting, even if variations in the optical outputs and average power are acceptable, the following other problems may occur.

[0009] As shown in Fig. 2, an AC-lighting type high-pressure discharge lamp lighting device is generally formed of combination of a step-down chopper circuit 11 and a polarity inverting circuit 12 (full bridge circuit). The polarity inverting circuit 12 constitutes a full bridge circuit including switching elements Q2 to Q5 formed of MOS-FET or the like as shown in Fig. 2 and a driving circuit 12a for driving the polarity inverting circuit 12 has a configuration as shown in Fig. 3(a). For example, IR2111S of IR Inc. is used as a driver IC12a1 and as shown in Fig. 3(b), a high potential-side switching element Q2 and a low potential-side switching element Q3 are turned ON/OFF, OFF/ON according to H/L of a full bridge control signal FB1'. A driving power source for the driving circuit 12a is directly supplied from a control power source Vcc for the low potential-side switching element Q3, and is supplied by applying electrical charge to a capacitor 3 through a diode D2 for the high potential-side switching element Q2. In a condition that the high potential-side switching element Q2 is turned OFF and the low potential-side switching element Q3 is turned ON, an electrical charge is applied to the capacitor C3 and conversely, in a condition that the high potential-side switching element Q2 is turned ON and the low potential-side switching element Q3 is turned OFF, the electrical charge applied to the capacitor C3 is discharged, thereby lowering the voltage (refer to a broken line in Fig. 4(c)). The same also applies to a driving circuit 12b on a side of the switching elements Q4, Q5.

[0010] According to the method of introducing a frequency which is lower than the normal lighting frequency for a predetermined period as disclosed in Patent Document 1 and Patent Document 2, a capacitance of the capacitor C3 as a driving power source for a high potential-side switching element of the driving circuit must be determined depending on the frequency which is lower than the normal lighting frequency and a capacitor with a larger capacitance is required as compared to the case of designing with the normal lighting frequency, thereby contributing to an increase in costs. In the case of a lamp current in a conventional example as shown in Fig. 4(a), in consideration of the capacitance of the capacitor C3, a lower limit value of the frequency which is lower than the normal lighting frequency only can be designed so as to ensure a voltage equal to or higher than a threshold voltage Vth capable of turning ON the high potential-side switching element Q2 as the voltage of the capacitor C3 as shown by a broken line in Fig. 4(c). Thus, a degree of freedom to define the lower limit (time tmax in Fig. 4) of the low frequency becomes small.

[0011] An object of the present invention is to provide a high pressure discharge lamp lighting device, in at least projection-type projectors using a liquid crystal device, which can reduce flickering of the high-pressure discharge lamp without being severely restricted by a circuit design factor with a high degree of freedom in design for each lamp and with a relatively simple control, according to a method other than the method of superimposing the pulse current on the lamp current.

[Means adapted to solve the Problems]

[0012] According to a first aspect of the present invention, to solve the above-mentioned problems, as shown in Fig. 2, a discharge lamp lighting device includes power feeding means 11 adapted to feed a predetermined amount of power to a high-pressure discharge lamp La, means 12 adapted to alternately invert polarity of a current fed to the high-pressure discharge lamp La, and control means 14 adapted to change a frequency alternately inverting the polarity and a duty ratio as a ratio of a period of a positive polarity to a period of a negative polarity, as shown in Fig. 1, upon start of lighting of the high-pressure discharge lamp La, after the high-pressure discharge lamp reaches a substantially stable state or reaches a predetermined lamp voltage, the high-pressure discharge lamp La is lighted in at least three lighting modes with predetermined average power put into the high-pressure discharge lamp La, in the lighting modes, a period of a positive polarity is nearly equal to a period of a negative polarity in a first mode, a period of a positive polarity is longer than a period of a negative polarity in a second mode, a period of a positive polarity is shorter than the a period of a negative polarity in a third mode, lighting frequencies in the second and third modes is equal to or less than a lighting frequency in the first mode, and each of periods t1, t2, t3 in the modes is at least one cycle, at least one first mode, at least one second mode and at least one third mode are collectively defined as one set and the one set is repeated.

[0013] According to a second aspect of the present invention, in the first aspect of the present invention, as shown in Fig. 8, in changing power put into the high-pressure discharge lamp, the lighting frequency is changed in at least one of the modes.

[0014] According to a third aspect of the present invention, in the first aspect of the present invention, as shown in Fig. 9, in changing power put into the high-pressure discharge lamp, the duty ratio is changed in at least either the second mode or the third mode.

[0015] According to a fourth aspect of the present invention, in the first aspect of the present invention, as shown in Fig. 10, in changing power put into the high-pressure discharge lamp, the period of is changed in at least one of the modes.

[0016] According to a fifth aspect of the present invention, in the first aspect of the present invention, as shown in Fig. 11, in changing power put into the high-pressure discharge lamp, at least two of items of the lighting frequency, the duty ratio, and the period in each of the modes are changed, when the changed item is the lighting frequency, the lighting frequency is changed in at least one of the first to third modes, when the changed item is the duty ratio, the duty ratio is changed in at least either the second mode or the third mode, and when the changed item is the period, the period is changed in at least one of the first to third modes.

[0017] According to a sixth aspect of the present invention, in any of the first to fifth aspects of the present invention, as shown in Fig. 12, according to a lamp voltage Vla of the high-pressure discharge lamp, at least one of items of the lighting frequency, the duty ratio and the period in each mode is changed, and when the changed item is the lighting frequency, the lighting frequency is changed in at least one of the first to third modes, when the changed item is the duty ratio, the duty ratio is changed in at least either the second mode or the third mode, and when the changed item is the period, the period is changed in at least one of the first to third modes.

[0018] According to a seventh aspect of the present invention, in any of the first to sixth aspects of the present invention, as shown in Fig. 13, a sum of the duty ratios in the second and third modes is not made equal to 100% and/or the period of the second mode is made different from the period of the third mode.

[0019] An eighth aspect of the present invention is an image display device including the high pressure discharge lamp lighting device according to any of the first to seventh aspect of the present invention (Fig. 15).

[Effect of the Invention]

[0020] According to the first aspect of the present invention, since a degree of freedom in setting the lighting frequency in the second or third mode which is introduced into a normal lighting frequency is improved and a power source for a driving circuit can be easily ensured, reduction in size and costs of circuits can be realized. Furthermore, variation in optical outputs and power can be made smaller, thereby advantageously reducing flickering of the high-pressure discharge lamp.

[0021] According to the second aspect of the present invention, since the lighting frequency is changed according to average power put into the high-pressure discharge lamp, a size of the protrusions can be made uniform or set to a desired value, and according to the average power put into the high-pressure discharge lamp, a condition for reducing flickering of the high-pressure discharge lamp can be set, thereby reducing flickering of the high-pressure discharge lamp.

[0022] According to the third aspect of the present invention, since the duty ratio is changed in the second or third mode according to average power put into the high-pressure discharge lamp, a range for melting the excessive protrusions can be changed, and according to the average power put into the high-pressure discharge lamp, a condition for reducing flickering of the high-pressure discharge lamp can be set, thereby reducing flickering of the high-pressure discharge lamp.

[0023] According to the fourth aspect of the present invention, since the period is changed in at least one mode according to the average power put into the high-pressure discharge lamp, even when the average power put into the high-pressure discharge lamp is changed, a condition for reducing flickering of the high-pressure discharge lamp can be set.

[0024] According to the fifth aspect of the present invention, in changing power put into the high-pressure discharge lamp, since at least two of the items of the lighting frequency, a duty ratio, and a period in each mode are changed, a size of the protrusions can be made uniform or set to a desired value according to the average power put into the high-pressure discharge lamp and a range for melting the excessive protrusions can be changed, and according to the average power put into the high-pressure discharge lamp, a condition for reducing flickering of the high-pressure discharge lamp can be set, thereby reducing flickering of the high-pressure discharge lamp.

[0025] According to the sixth aspect of the present invention, since at least one of the items of the lighting frequency, the duty ratio, and the period in each mode is changed, a size of the protrusions can be made uniform or set to a desired value according to the lamp voltage of the high-pressure discharge lamp and a range for melting the excessive protrusions can be changed, and according to the average power put into the high-pressure discharge lamp, a condition for reducing flickering of the high-pressure discharge lamp can be set, thereby reducing flickering of the high-pressure discharge lamp.

[0026] According to the seventh aspect of the present invention, since the sum of the duty ratios in the second and third modes is not made equal to 100% and/or a period of the second mode is made different from that of the third mode, even when temperature distribution of both electrodes becomes unbalanced due to an air cooling condition of the high-pressure discharge lamp and an attachment of a reflector, the temperature of the both electrodes can be made uniform by making the duty ratio or the period in the second mode different from that in the third mode, resulting in reduction of flickering of the high-pressure discharge lamp.

[0027] According to the eighth aspect of the present invention, since the high pressure discharge lamp lighting device according to any of the first to seventh aspects of the present invention is provided, an image display device with less flickering of the high-pressure discharge lamp can be provided.

[Best Mode for Carrying Out the Invention]

(First embodiment)

[0028] Upon start of lighting of a discharge lamp, after the discharge lamp reaches a substantially stable state or reaches a predetermined lamp voltage, as shown in Fig. 1, a high pressure discharge lamp lighting device in the present embodiment lights the discharge lamp in at least three modes with the respective average power put into the discharge lamp.

[0029] A duty ratio of a lighting frequency is 50% in a "mode 1" as a first mode, a duty ratio of a lighting frequency is larger than 50% (80% in an example) in a "mode 2" as a second mode, and a duty ratio of a lighting frequency is smaller than 50% (20% in the example) in a "mode 3" as a third mode. Lighting frequencies f2, f3 in the mode 2 and the mode 3 are equal to or less than a lighting frequency f1 in the mode 1, each of periods t1, t2, t3 of the respective modes is at least one cycle, at least one mode 1, and at least one mode 2 and at least one mode 3 are collectively defined as one set ("the mode 2, the mode 1, the mode 3, the mode 1" in this order are collectively defined as one set in the example) and the one set is repeated.

[0030] Fig. 2 is a circuit diagram of a high pressure discharge lamp lighting device for controlling according to the present invention. This lighting device is formed by combining a step-down chopper circuit 11 and a polarity inverting circuit 12. A DC voltage outputted from a power supply circuit E is lowered to a suitable voltage by the step-down chopper circuit 11 and converted into a rectangular wave AC voltage by the polarity inverting circuit 12. An output of the polarity inverting circuit 12 is connected with a starting resonance circuit 13 formed of a capacitor C2 and an inductor L2 and the discharge lamp La is connected to both ends of the capacitor C2.

[0031] The power supply circuit E is formed of, for example, rectifying means adapted to rectify a commercial AC power source and a step-up chopper circuit for power factor improvement and smoothing, and outputs a DC voltage of, for example, a few hundreds V

[0032] The step-down chopper circuit 11 includes: a switching element Q1 switched at high frequencies; an inductor L1 for energy accumulation; a diode D1 for passing a regenerating current; a smoothing capacitor C1; and a resistor R1 for current detection, and lowers the DC voltage outputted from the power supply circuit E by variably controlling a pulse width of the switching element Q1 to charge the capacitor C1.

[0033] The polarity inverting circuit 12 is a full bridge inverter circuit including a series circuit formed of switching elements Q2, Q3 connected to both ends of the capacitor C1 in parallel and a series circuit formed of switching elements Q4, Q5, and inverts a polarity of the DC voltage of the capacitor C1 by alternately switching between the state where switching elements Q2, Q5 are turned ON and the switching elements Q3, Q4 are turned OFF and the state where the switching elements Q2, Q5 are turned OFF and the switching elements Q3, Q4 are turned ON to feed a rectangular wave AC voltage to a load circuit.

[0034] The load circuit includes the resonance circuit 13 formed of the capacitor C2 and the inductor L2 and the discharge lamp La connected to the both ends of the capacitor C2 in parallel. The discharge lamp La is a high-intensity high-pressure discharge lamp (HID lamp) such as a high-pressure mercury lamp and a metal halide lamp.

[0035] To start lighting of the discharge lamp La, the control circuit 14 applies a high frequency voltage of a few dozens of kHz to a few hundreds of kHz to both ends of the resonance circuit 13 by alternately turning ON/OFF the diagonally-located switching elements Q2, Q5 and the switching elements Q3, Q4. This high frequency voltage is raised by a resonance effect of the resonance circuit 13, thereby generating a high resonance voltage in the capacitor C2, and the voltage is applied to the discharge lamp La. The discharge lamp La is lighted by dielectric breakdown thus generated. The discharge lamp La is operated for some time (a few hundreds of msec to a few dozens of seconds) with high frequencies to cause arc discharge and then, is subjected to a rectangular wave voltage with low frequencies of a few dozens of kHz to a few hundreds of kHz to maintain its lighting.

[0036] Although not shown, in addition to the resonance circuit 13, an igniter circuit for generating a high voltage pulse for starting or restarting the discharge lamp La may be provided. The igniter circuit may allow the polarity inverting circuit 12 to start at the high frequency operation. Alternatively, the polarity inverting circuit 12 may be operated with low frequencies from the beginning and discharge lamp La may be lighted by dielectric breakdown with the high voltage pulse of the igniter circuit.

[0037] A voltage detecting circuit 15 divides an output voltage of the step-down chopper circuit 11 by a series circuit formed of resistors R2, R3 and detects the voltage. The detected output of the voltage detecting circuit 15 is inputted to a microcomputer 20 of the control circuit 14 and converted into a digital value by an A/D converter 21. According to the voltage value detected by the lamp voltage detecting circuit 15, a power control reference signal generating and processing part 22 of the microcomputer 20 calculates a lamp power control amount with reference to a data table 23, and a D/A converter 16 converts the voltage into a power command voltage Ip. The D/A converter 16 uses, for example, an R-2R resistor ladder circuit. A PWM control circuit 17 performs chopper control to control lamp power (lamp current) by comparing a detected voltage of a chopper current detected by the current detecting resistor R1 with the power command voltage Ip.

[0038] For example, R8C/26, 27 group and R8C/2E, 2F of RBC/Tiny series of Renesas Technology Corp. are used as the microcomputer 20 of the control circuit 14. Fig. 2 shows functions of the microcomputer 20 in blocks.

[0039] A time measuring and setting processing part 24 performs a timing control of polarity inversion and time measurement in the polarity inverting circuit 12 and outputs full bridge control signals FB1, FB2 to a full bridge control part 12c.

[0040] The driving circuit 12a is constituted as shown in Fig. 3(a) and controls so as to alternately turn ON/OFF the high potential-side switching element Q2 and the low potential-side switching element Q3 according to a full bridge control signal FB1' from the full bridge control part 12c. The driving circuit 12b is also constituted as shown in Fig. 3(a) and controls so as to alternately turn ON/OFF the high potential-side switching element Q4 and the low potential-side switching element Q5 according to a full bridge control signal FB2' from the full bridge control part 12c.

[0041] A power determination processing part 25 receives an average power setting signal CS1 from an image display device in response to an output signal of an average power change signal receiving circuit formed of a photocoupler PC1 and a resistor R4, and determines power instructed from the image display device side. Average power (current) put into the discharge lamp La is instructed through, for example, UART communication and the like. By adapting a communication command and the like to the image display device side and receiving the command, the discharge lamp lighting device outputs average power (current) conforming to the command.

[0042] The data table 23 stores power control amount data (a plurality of power values) corresponding to the lamp voltages Vla therein. Desired power (current) for each Vla is set in the power control amount data as shown in Fig. 6(a). In an example shown in Fig. 6(a), although two kinds of data: full lighting (Full) and dimming lighting (Dim) are prepared, the number of kinds is not limited.

[0043] The data table 23 also stores, as described later, data on timing (frequency, duty ratio) of polarity inversion of the polarity inverting circuit 12 and each period (time and the number of times of polarity inversion) according to each average power and lighting mode therein. Timing (frequency, duty ratio) of polarity inversion and each period (time and the number of times of polarity inversion) in each average power and lighting mode are calculated with reference to the data table 23 to control the polarity inverting circuit 12.

[0044] A lamp ON/OFF determination processing part 26 receives a high-pressure discharge lamp ON/OFF signal CS0 from the image display device in response to an output signal of a high-pressure discharge lamp ON/OFF signal receiving circuit formed of a photocoupler PC2 and a resistor R5.

[0045] When turning ON (lighting) of the high-pressure discharge lamp is instructed according to the high-pressure discharge lamp ON/OFF signal CS0 from the image display device side, the polarity inverting circuit 12 is operated with high frequencies, thereby generating a high voltage due to a resonance effect of the resonance circuit 13. As a result, the discharge lamp La is started with dielectric breakdown, the polarity inverting circuit 12 shifts to the low frequency operation and then, according to a control characteristic shown in Fig. 6(a), a lamp current I1a and lamp power Wla are controlled depending on the lamp voltage Vla.

[0046] In a lamp current control (lamp power control), as shown in Fig. 6 (a), a constant current control to make the lamp current Ila constant (= Ila0) is performed until the lamp voltage Vla reaches V0 (at dimming: V0') and the constant power control to make the lamp power Wla constant is performed after the lamp voltage Vla has reached V0 (at dimming: V0').

[0047] Fig. 6 (b) shows this control on time basis. Fig. 6 (b) shows variations in the lamp power Wla, the lamp current Ila, and the lamp voltage Vla with time after the discharge lamp La is started. The lamp current Ila is controlled to be constant (= Ila0) by time t0 according to the constant current control, and when the lamp voltage Vla rises and reaches a predetermined lamp voltage V0 (at dimming: V0'), the constant current control shifts to the constant power control. After that, the lamp voltage Vla rises to the lamp voltage V1determined depending on the state of the discharge lamp La (applied power, the electrode state (distance between electrodes) and the air cooling condition} and is stabilized.

[0048] For example, in Fig. 6(b), after the discharge lamp has reached the substantially stable state (t = about ta) or the lamp voltage has reached the lamp voltage V0 (at dimming: V0') at which the constant power control is started, as shown in Fig. 1, the three lighting modes are combined to light the discharge lamp.

[0049] In the mode 1 (the first lighting mode), a lighting frequency f1 is generally selected from a range of 50Hz to 1kHz, a duty ratio is 50% and the period is t1 (at least one cycle of the lighting frequency f1), in the mode 2 (the second lighting mode), a lighting frequency f2 is selected from the range of the lighting frequency f1 or less, the duty ratio is 80%, and the period is t2 (at least one cycle of the lighting frequency f2), and in the mode 3 (the third lighting mode), a lighting frequency f3 selected from the range of the lighting frequency f1 or less, the duty ratio is 20%, and the period is t3 (at least one cycle of the lighting frequency f3). In an example shown in Fig. 1, the lighting frequencies f2, f3 in the mode 2 and the mode 3 are the same as the lighting frequency f1 in the mode 1 (f1 = f2 = f3), the period of each mode is one cycle or more and t1 > t2 = t3, the mode 1, the mode 2 and the mode 3 are collectively defined as one set in the order of "mode 2, mode 1, mode 3, mode 1" and the one set is repeated. The reason why the period of the mode 2 is the same as the period of the mode 3 and the sum of the duty ratios in the second and third modes is set to 100% is that temperature distribution of electrodes A, B (refer to Fig. 14) is made uniform.

[0050] According to the present invention, as contradistinguished in Figs. 4(a), (b), as compared to the conventional examples disclosed in Patent Documents 1, 2, it is possible to raise the low frequency introduced into the normal lighting frequency and reduce variation ranges in an optical output and power relative to the normal lighting frequency, thereby reducing flickering.

[0051] In addition, as represented by a solid line in Fig. 4(c), in the second and third modes, variation in the voltages of the capacitor C3 as a driving power source for the high potential-side switching element Q2 of the driving circuit 12a in the polarity inverting circuit 12 is reduced. As represented by the lamp current in a conventional example (Fig. 4(a)), at a frequency which is lower than the normal lighting frequency, a limit of a period which can be introduced (time tmax in Fig. 4(c)) is restricted by the condition that a threshold voltage Vth or more capable of turning ON the high potential-side switching element Q2 is maintained. On the contrary, by controlling as in the lamp current of the present invention (Fig. 4(b)), since an electrical charge is charged in the capacitor C3 as a high potential-side driving power source while the high potential-side switching element Q2 is turned OFF, as compared to the art disclosed in Patent Documents 1, 2, in the case where a capacitance of the capacitor C3 is the same, the limit tmax of the setting value is extended, and in the case where the time tmax is the same as in Patent Documents 1, 2, the capacitance of the capacitor C3 can be reduced.

[0052] In other words, a degree of freedom in setting the low frequency introduced into the normal lighting frequency and an introduction time is improved, realizing reduction in size and costs of circuits.

[0053] In addition, it is possible to form protrusions on the electrodes in the first mode, raise an electrode temperature of the high-pressure discharge lamp in the second and third modes to nearly the same temperature as that in the techniques disclosed in Patent Documents 1 and 2 as shown in Figs. 5 (the similar effect to the effect in the Patent Documents 1 and 2 can be obtained), and melt excessive protrusions, which can prevent the excessive protrusions from being generated. As a result, flickering of the high-pressure discharge lamp can be reduced.

[0054] Here, for a relationship between a temperature of an electrode A and a temperature of an electrode B in the discharge lamp La (refer to Fig. 14), the electrode temperature T in Fig. 5 represents, for example, the temperature of the electrode A, and when the electrodes A, B are balanced in temperature, the electrode temperature of the electrode B is vertically inverted from the electrode temperature of the electrode A with respect to the electrode temperature T1.

[0055] Even if the frequencies f1, f2, f3 in the modes 1, 2, 3 are the same (even if the frequency is not lowered in the modes 2, 3), it is possible to form protrusions on the electrodes in the mode 1, raise the electrode temperature in the discharge lamp in the mode 2 and the mode 3, and melt excessive protrusions. As a result, flickering of the discharge lamp can be reduced.

[0056] Since the optical output lowers at the time when the polarity of the lamp current flowing to the discharge lamp is changed, when a frequency which is lower than the normal lighting frequency exists, the optical output per unit time varies depending on an extent of variation in the frequencies, thereby possibly causing flickering due to variation in the frequencies. If the frequencies in the modes are uniform, the number of times the polarity of the lamp current flowing to the discharge lamp is inverted remains unchanged, and flickering due to variation in the frequencies does not occur.

[0057] Furthermore, since the power put into the discharge lamp also lowers at the time when the polarity of the lamp current flowing to the discharge lamp is changed, an average power value varies depending on the number of times of polarity inversion. When a variation range in the average power values becomes problematic, a power control amount needs to be controlled to be corrected so that the average power in the normal lighting frequency may be substantially the same as that in the low frequency. It is preferred that the frequencies in the respective modes are uniform in terms of reduction in flickering and easiness of design of power control.

[0058] The lighting modes may be combined as shown in Fig. 7. The same applies to the below-mentioned embodiments.

[0059] Fig. 7(b1) shows a combination example similar to that in Fig. 1, and the modes 1 to 3 in Fig. 7(a) are collectively defined as one set in the order of mode 2, mode 1, mode 3, mode 1 and the one set is repeated.

[0060] In an example shown in Fig. 7(b2), the modes 1 to 3 are collectively defined as one set in the order of mode 2, mode 3, mode 1 and the one set is repeated.

[0061] In an example shown in Fig. 7(b3), the modes 1 to 3 are collectively defined as one set in the order of mode 2, mode 3, mode 2, mode 1, mode 3, mode 2, mode 3, mode 1 and the one set is repeated.

[0062] In an example shown in Fig. 7(b4)), the modes 1 to 3 are collectively defined as one set in the order of mode 2, mode 3, mode 2, mode 3, mode 1 and the one set is repeated.

[0063] The order, the number of repetition and combination of the lighting modes are not limited and may be set to be suitable for lighting conditions (power, air cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

[0064] Furthermore, the lighting frequency in each of the first to third modes, the duty ratio in each of the second mode and the third mode, and a period (time) of each of the first to third modes and magnitude correlation thereof are not limited, and may be set to values suitable for the lighting conditions (power, air cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

[0065] With the above-mentioned configuration and operation, costs of the circuits can be reduced, the degree of freedom in design adapted to the respective high-pressure discharge lamps is improved without being restricted by circuit design factors, and flickering of the high-pressure discharge lamp can be reduced with a relatively simple control (a control of the lighting frequency, the duty ratio and the period).

(Second embodiment)

[0066] In the present embodiment, in changing power put into the high-pressure discharge lamp, the lighting frequency is changed in at least one of the modes. A circuit configuration may be the same as in the first embodiment.

[0067] Fig. 8 shows an example of operation in the present embodiment. In the case where the average power put into the high-pressure discharge lamp is changed from power P1 to power P2, the lighting frequency of the first lighting mode is changed from f1 to f1'. In the case where the average power put into the high-pressure discharge lamp is changed from the power P2 to the power P1, the lighting frequency of the first lighting mode is changed from f1' to f1. In an example shown in Fig. 8, when the power P1 is larger than the power P2, the frequency f1 is made larger than the frequency f1'.

[0068] In this example, the first lighting mode is a period in which the protrusions are generated on the electrodes, and is the case in which a size of the protrusions is made remained substantially the same before and after change of the power. Generally speaking, since the electrode temperature lowers as power (current) becomes smaller, a size of the protrusions is decreased, as the lighting frequency is lower, the size of the protrusions is increased. In the case where small protrusions are acceptable, the frequency may remain unchanged or be increased.

[0069] In an example shown in Fig. 8, the two types of power P1, P2 are put into the high-pressure discharge lamp. However, three or more types of power can similarly change the lighting frequency.

[0070] The lighting mode for changing the lighting frequency is not limited to the first lighting mode and may be the second lighting mode or the third lighting mode. The order of the lighting modes is not limited to the order shown in Fig. 8.

[0071] Fluctuation correlation of the power and the frequency is not limited to that shown in Fig. 8 and may be set to be suitable for the lighting conditions (power, air cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

(Third embodiment)

[0072] In the present embodiment, in changing power put into the high-pressure discharge lamp, the duty ratio is changed in at least either the second mode or the third mode. A circuit configuration may be the same as that of the first embodiment.

[0073] Fig. 9 shows an example of an operation in the present embodiment. In the case where the average power put into the high-pressure discharge lamp is P1, the duty ratio in the second lighting mode is 80% and the duty ratio in the third lighting mode is 20%, and when the average power put into the high-pressure discharge lamp is P2 (< P1), the duty ratio in the second lighting mode is 90% and the duty ratio in the third lighting mode is 10%.

[0074] In this example, the second and the third modes are periods in which the surface temperature of the electrodes is raised and the excessive protrusions are melt so as not to generate a plurality of protrusions such that in the case where the applied power is small, a control is carried out to increase imbalance of the duty ratio. This is due to that, since, in general, an electrode temperature lowers and the temperature range for melting is narrowed when a current becomes small, a period during which an electrode is an anode is extended, thereby raising a surface temperature of the electrodes to extend a desired temperature range.

[0075] In an example shown in Fig. 9, the two types of power P1, P2 are put into the high-pressure discharge lamp. However, three or more types of power can similarly change the duty ratio.

[0076] The lighting mode for changing the duty ratio may be either the second lighting mode or the third lighting mode. The order of the lighting modes is not limited to the order shown in Fig. 9.

[0077] Values of the duty ratio before and after change are not limited to values shown in Fig. 9.

[0078] Fluctuation correlation of the power and the duty ratio is not limited to that shown in Fig. 9 and may be set to be suitable for the lighting conditions (power, air cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

(Fourth embodiment)

[0079] In the present embodiment, in changing power put into the high-pressure discharge lamp, a period is changed in at least one of the modes. A circuit configuration may be the same as that of the first embodiment.

[0080] Fig. 10 shows an example of an operation in the present embodiment. When the average power put into the high-pressure discharge lamp is P1, periods (time) of the second and third lighting modes are t2 respectively, and in the case where the average power put into the high-pressure discharge lamp is P2 (< P1), the period (time) of the second and third lighting modes is t2'(> t2).

[0081] In this example, the second and the third modes are periods in which the surface temperature of the electrodes is raised and the excessive protrusions are melt so as not to generate a plurality of protrusions such that when applied power is small, a control is carried out to increase the period. This is due to that, since, in general, the electrode temperature lowers and the temperature range for melting protrusions is narrowed when the power (current) becomes small, a total period during in which the electrode is an anode is extended, thereby raising the surface temperature of the electrodes to extend a desired temperature range.

[0082] In an example shown in Fig. 10, the two types of power P1, P2 are put into the high-pressure discharge lamp. However, three or more types of power can similarly change the period (time).

[0083] The lighting mode for changing the period (time) may be the first lighting mode, or either the second lighting mode or the third lighting mode, that is, the period (time) only needs to be changed in at least one lighting mode. The order of the lighting modes is not limited to the order shown in Fig. 10.

[0084] The period (time) before and after change is not limited to that shown in Fig. 10.

[0085] Magnitude correlation of the power and the period in each mode is not limited to that in Fig. 10 and may be set to suitable for the lighting conditions (power, air-cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

(Fifth embodiment)

[0086] In the present embodiment, in changing power put into the high-pressure discharge lamp, at least two of items of a lighting frequency, a duty ratio and a period in each mode are changed, and in the case where the changed item is the lighting frequency, the lighting frequency is changed in at least one of the first to third modes, when the changed item is the duty ratio, the duty ratio is changed in at least either the second mode or the third mode, and when the changed item is the period, the period is changed in at least one of the first to third modes. A circuit configuration may be the same as that of the first embodiment.

[0087] Fig 11 shows an example of an operation in the present embodiment. In the case where the average power put into the high-pressure discharge lamp is changed from the power P1 to the power P2, the lighting frequency of the first lighting mode is changed from f1 to f1'. In the case where the average power put into the high-pressure discharge lamp is changed from the power P2 to the power P1, the lighting frequency of the first lighting mode is changed from f1' to f1. In an example shown in Fig. 11, when the power P1 is larger than the power P2, the frequency f1 is made larger than the frequency f1'.

[0088] In the case where the average power put into the high-pressure discharge lamp is P1, a duty ratio in the second lighting mode is set to 80% and the duty ratio in the third lighting mode is set to 20%, and when the average power put into the high-pressure discharge lamp is P2 (< P1), the duty ratio in the second lighting mode is set to 90% and the duty ratio in the third lighting mode is set to 10%.

[0089] Furthermore, in the case where the average power put into the high-pressure discharge lamp is P1, the period (time) of the second and third lighting modes is set to t2, and when the average power put into the high-pressure discharge lamp is P2 (< P1), the period (time) of the second and third lighting modes is set to t2' (> t2).

[0090] In this example, the first mode is a period in which the protrusions are generated on the electrodes and a size of the protrusions is made nearly uniform before and after change of the power. This is due to that, generally, as the power (current) becomes smaller, the electrode temperature lowers and the size of the protrusions is decreased, and as the lighting frequency is lower, the size of the protrusions is increased. In the case where small protrusions are acceptable, the frequency may remain unchanged or be increased.

[0091] The period of the second and third modes are periods in which a surface temperature of electrodes is raised and the excessive protrusions are melted so as not to generate a plurality of protrusions such that in the case where the applied power is small, a control is carried out to increase the period when the applied power is small. This is due to that, generally, since the electrode temperature lowers and a temperature range for melting is narrowed when the power (current) becomes small, a time or the total time during which the electrode is an anode is extended, thereby raising the surface temperature of the electrodes to extend a desired temperature range.

[0092] In an example shown in Fig. 11, the two types of power P1, P2 are put into the high-pressure discharge lamp. However, three or more types of power can similarly change the lighting frequency, the duty ratio and the period (time) in the modes.

[0093] The lighting mode for changing the lighting frequency is not limited to the first lighting mode and may be the second lighting mode or the third lighting mode.

[0094] A lighting mode for changing the duty ratio may be either the second lighting mode or the third lighting mode.

[0095] A lighting mode for changing the period (time) may be the first lighting mode, or either the second lighting mode or the third lighting mode, that is, a period (time) only needs to be changed in at least one lighting mode. The order of the lighting modes is not limited to the order shown in Fig. 11.

[0096] The frequency, the duty ratio, and the period (time) before and after change are not limited and may be set to values suitable for the lighting conditions (power, air cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

(Sixth Embodiment)

[0097] In the present embodiment, in any of the above-mentioned first to fifth embodiments, according to the lamp voltage Vla of the high-pressure discharge lamp, at least one of items of a lighting frequency, a duty ratio, and a period in each mode is changed, in the case where the changed item is the lighting frequency, the lighting frequency is changed in at least one of the first to third modes, when the changed item is the duty ratio, the duty ratio is changed in at least either the second mode or the third mode and when the changed item is the period, the period is changed in at least one of the first to third modes. A circuit configuration may be the same as that of the first embodiment.

[0098] Figs. 12 show an example of an operation in the present embodiment. Fig. 12(a) shows a relationship between the lamp voltage Vla and the average power Wla put into the high-pressure discharge lamp La, Fig. 12(b) shows a relationship between the lamp voltage Vla and the current Ila put into the high-pressure discharge lamp La, Fig. 12(c) shows a relationship between the lamp voltage Vla and the frequency for lighting the high-pressure discharge lamp La, Fig. 12(d) shows a relationship between the lamp voltage Vla and the duty ratio of the lamp current, and Fig. 12(e) shows a relationship between the lamp voltage Vla and the period (time) of the first to third modes.

[0099] Upon start of lighting of the high-pressure discharge lamp, after the high-pressure discharge lamp has reached the predetermined lamp voltage V0, at least one first mode, at least one second mode and at least one third mode are collectively defined as one set and the one set is repeated. In this example, the lighting frequency and the period (time) of the second mode are made equal to those of the third mode, and the sum of the duty ratios in the second and third modes is set to 100%.

[0100] As shown in Fig. 12(c), the lamp voltage V1 is defined as a threshold value, and when the lamp voltage Vla becomes higher than the threshold value V1, the lighting frequency in the first lighting mode is changed from f1 to f1' and the lighting frequencies in the second and third lighting modes are changed from f2 to f2'. When the lamp voltage Vla becomes equal to or less than the threshold value V1, the lighting frequency in the first lighting mode is changed from f1' to f1 and the lighting frequencies in the second and third lighting modes are changed from f2' to f2. Here, f1 is set to be larger than f1' and f2 is set to be larger than f2'.

[0101] In this example, the first mode is a period in which the protrusions are generated on the electrodes, and is the case in which the size of the protrusions is made remained substantially the same before and after the threshold V1 of the lamp voltage Vla. Generally speaking, as power (current) becomes smaller, the electrode temperature lowers and a size of the protrusions is decreased, and as the lighting frequency is lowered, the size of the protrusions is increased. In the case where small protrusions are acceptable, the frequency may remain unchanged or be increased.

[0102] As shown in Fig. 12(d), a duty ratio of the first lighting mode still remains to be 50% and a duty ratios of the second and third lighting modes is changed before and after the threshold value V1 of the lamp voltage Vla. In other words, the lamp voltage V1 is defined as the threshold value, and when the lamp voltage Vla becomes higher than the threshold value V1, the duty ratio of the second lighting mode is changed from duty2 to duty2'. When the lamp voltage Vla becomes equal to or less than the threshold value V1, the duty ratio of the second lighting mode is changed from duty2' to duty2.

[0103] In the present embodiment, the sum of the duty ratios in the second and third mode is set to 100%. In other words, when the lamp voltage Vla becomes higher than the threshold value V1, the duty ratio of the third lighting mode is changed from (100 - duty2) to (100 - duty2'). When the lamp voltage Vla becomes equal to or less than the threshold value V1, the duty ratio of the third lighting mode is changed from (100 - duty2') to (100 - duty2). In this example, duty2 is set to be smaller than duty2', for example, duty2 is 80% and duty2' is 90%.

[0104] Furthermore, as shown in Fig. 12(e), the period (time) of the first lighting mode still remains to be t1 and the period (time) in the second and third lighting modes is changed before and after the threshold value V1 of the lamp voltage Vla. In other words, the lamp voltage V1 is defined as the threshold value, and when the lamp voltage Vla becomes higher than the threshold value V1, the period (time) of the second and third lighting modes is changed from t2 to t2', and when the lamp voltage Vla becomes equal to or less than the threshold value V1, the periods (time) of the second and third lighting modes are changed from t2' to t2. Here, t2 is set to be smaller than t2'.

[0105] In this example, the second and third modes are periods in which the surface temperature of the electrodes is raised and the excessive protrusions are melt so as not to generate a plurality of protrusions, and when the current becomes small, the electrode temperature lowers and the temperature range for melting protrusions is narrowed. Thus, in order to extend each time or the total time during which the electrode is an anode, thereby raising the surface temperature of the electrodes to extend a desired temperature range, duty2 is set to be smaller than duty2' and t2 is set to be smaller than t2'.

[0106] In an example shown in Figs. 12, although the threshold value of the lamp voltage Vla is only one threshold point, that is, V1, even when there are a plurality of threshold points, the lighting frequency, the duty ratio and the period (time) may be similarly changed before and after the threshold points. In addition, although the lighting frequency, the duty ratio, the period (time) and the like are changed in a stepped manner herein, these may be continuously changed depending on increase/decrease in the lamp voltage Vla.

[0107] The lighting mode for changing the lighting frequency may be one or two lighting modes or all of the three lighting modes.

[0108] The lighting mode for changing the duty ratio may be either the second lighting mode or the third lighting mode.

[0109] The lighting mode for changing the period (time) may be the first lighting mode, or either the second lighting mode or the third lighting mode, that is, the period (time) may be only needs to be changed in at least one lighting mode. The order of the lighting modes is not limited.

[0110] Furthermore, magnitude correlation of the frequency, magnitude correlation of the duty ratio, magnitude correlation of the period (time), specific values of the frequency, specific values of the duty ratio, and specific period (time) before and after the threshold value of the lamp voltage are not limited, and may be set to values suitable for the lighting conditions (power, air cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

(Seventh embodiment)

[0111] In the present embodiment, in any of the above-mentioned first to sixth embodiments, the sum of the duty ratios in the second and third modes is not made equal to 100%, and/or the period of the second mode is made different from the period of the third mode. A circuit configuration may be the same as that of the first embodiment.

[0112] Figs. 13 show examples of an operation in the present embodiment. Three lighting modes for the high-pressure discharge lamp shown in Fig. 13(a) are combined, and as shown in Figs. 13(b1) to (b3), one set formed of the mode 2, the mode 1, the mode 3, the mode 1 in this order is repeated to light the high-pressure discharge lamp. In the mode 1, the lighting frequency is f1, the duty ratio is 50%, the period (time) is t1, and in the mode 2 and the mode 3, the lighting frequency is f2.

[0113] The duty ratio and the period (time) in the modes 2, 3 are set as follows.

[0114] In an example shown in Fig. 13(b1), the period (time) of the mode 2 is made equal to that of the mode 3 (= t2) and the sum of the duty ratios in the modes 2, 3 is controlled so as not to equal to 100%, for example, the duty ratios in the mode 2 and the mode 3 are set to 80%, 40%, respectively. In this example, the ratio of a positive direction to a negative direction of the current direction in the high-pressure discharge lamp is 60:40 in total.

[0115] In an example shown in Fig. 13(b2), the sum of the duty ratios in the mode 2 and the mode 3 is set to 100% (the ratio of the positive direction to the negative direction of the current direction in the high-pressure discharge lamp is 50:50) and the period (time) of the mode 2 and the period (time) of the mode 3 are defined as t2, t3, respectively (t2 > t3).

[0116] In an example shown in Fig. 13(b3), the sum of the duty ratios in the mode 2 and the mode 3 is set to be different from 100%, for example, the duty ratio in the mode 2 and the duty ratio in the mode 3 are 80%, 40%, respectively (the ratio of the positive direction to the negative direction of the current direction in the high-pressure discharge lamp is 60:40), and the period (time) of the mode 2 and the period (time) of the mode 3 are defined as t2, t3, respectively (t2 > t3).

[0117] In other words, according to the control as shown in Figs. 13(b1) to (b3), when temperature distribution of the electrodes A, B becomes imbalanced by the air cooling condition of the high-pressure discharge lamp La and attachment of a reflector R to the high-pressure discharge lamp La as shown in Fig. 14, each value is set so as to make the temperature of the electrodes A, B uniform.

[0118] The number of times the lighting modes are repeated, the order of the lighting modes, magnitude correlation of the power, magnitude correlation of the frequency and magnitude correlation of the period (time) are not limited to those shown in Figs. 13. Specific values of the lighting frequency, the duty ratio and the period (time) are not limited and may be set to values suitable for the lighting conditions (power, air cooling condition and the like) of the high-pressure discharge lamp so as not to generate flickering of the lamp.

(Eighth embodiment)

[0119] The high pressure discharge lamp lighting device in each of the above-mentioned embodiments is used to light the high-pressure discharge lamp as a light source for a projector. Fig. 15 is a schematic view showing an internal configuration of the projector. The figure shows a floodlight window 31, a power source part 32, cooling fans 33a, 33b, 33c, an external signal input part 34, an optical system 35, a main control board 36, a discharge lamp lighting device 40 and a discharge lamp La. The main control board is installed in a frame represented by a broken line. Image display means (transmission -type liquid crystal display element or a reflection-type image display element) for transmitting or reflecting light from the discharge lamp La is provided in the middle of the optical system 35, and the optical system 35 is designed so as to project the transmission light or the reflection light through the image display means on a screen. In this manner, the discharge lamp lighting device 40 along with the discharge lamp La is installed in the projector 30. By adopting the discharge lamp lighting device of the present invention, flickering of the lamp can be reduced, thereby enabling reduction in size and costs of the lighting device.

[0120] The high pressure discharge lamp lighting device of the present invention may be applied to the image display device in which a projector and a screen are integrated, such as a rear projection television. The high pressure discharge lamp lighting device of the present invention may be also applied to general light sources other than the image display device such as indoor or outdoor illumination fixtures.

[Brief Description of the Drawings]

[0121]

[Fig.1] Fig. 1 is an explanatory view showing an operation in a first embodiment according to the present invention.

[Fig.2] Fig. 2 is a circuit diagram showing a circuit configuration in the first embodiment according to the present invention.

[Fig.3] Figs. 3 are explanatory views describing a driving circuit used in the first embodiment of the present invention, Fig. 3(a) is a circuit diagram showing a configuration of a driving circuit and Fig. 3(b) is a waveform chart showing an operation of the driving circuit.

[Fig.4] Figs. 4 are explanatory views showing comparison of attenuation of a power source voltage in a driving circuit of the present invention with that of a conventional example.

[Fig.5] Figs. 5 are explanatory views showing comparison of variation in an electrode temperature of the present invention with that of a conventional example.

[Fig.6] Figs. 6 are characteristic views showing an operation in the first embodiment of the present invention.

[Fig.7] Figs. 7 are explanatory views showing combination of lighting modes in the first embodiment of the present invention.

[Fig.8] Fig. 8 is an explanatory view showing an operation in a second embodiment according to the present invention.

[Fig.9] Fig. 9 is an explanatory view showing an operation in a third embodiment according to the present invention.

[Fig.10] Fig. 10 is an explanatory view showing an operation in a fourth embodiment according to the present invention.

[Fig.11] Fig. 11 is an explanatory view showing an operation in a fifth embodiment according to the present invention.

[Fig.12] Figs. 12 are explanatory views showing an operation in a sixth embodiment according to the present invention.

[Fig.13] Figs. 13 are explanatory views showing an operation in a seventh embodiment according to the present invention.

[Fig.14] Fig. 14 is a view schematically showing a configuration of a high-pressure discharge lamp used in a high pressure discharge lamp lighting device according to the present invention.

[Fig.15] Fig. 15 is a view schematically showing a configuration of an image display device mounted with a high pressure discharge lamp lighting device according to the present invention therein.

[Description of Reference Numerals]

[0122]

E	DC power supply circuit
11	Step-down chopper circuit
12	Polarity inverting circuit
14	Control circuit
La	High-pressure discharge lamp

Claims

1. A high pressure discharge lamp lighting device comprising:

power feeding means adapted to feeding a predetermined amount of power to a high-pressure discharge lamp;
means adapted to alternately invert a polarity of a current fed to the high-pressure discharge lamp; and
control means capable of changing a frequency alternately inverting the polarity and a duty ratio as a ratio of a period of a positive polarity to a period of a negative polarity, wherein:

upon start of lighting of the high-pressure discharge lamp, after the high-pressure discharge lamp reaches a substantially stable state or reaches a predetermined lamp voltage, the high-pressure discharge lamp is lighted in at least three lighting modes with a predetermined average power put into the high-pressure discharge lamp,
in the lighting modes, a period of a positive polarity is nearly equal to a period of a negative polarity in a first mode, a period of a positive polarity is longer than a period of a negative polarity in a second mode, and a period of a positive polarity is shorter than a period of a negative polarity in a third mode,
lighting frequencies in the second mode and the third mode is equal to or less than a lighting frequency in the first mode, and
each of periods t1, t2, t3 in the modes is at least one cycle, at least one first mode, at least one second mode and at least one third mode are collectively defined as one set and the one set is repeated.

2. The high pressure discharge lamp lighting device according to claim 1, wherein in changing power put into the high-pressure discharge lamp, the lighting frequency is changed in at least one of the modes.

3. The high pressure discharge lamp lighting device according to claim 1, wherein in changing power put into the high-pressure discharge lamp, the duty ratio is changed in at least either the second mode or the third mode.

4. The high pressure discharge lamp lighting device according to claim 1, wherein in changing power put into the high-pressure discharge lamp, the period is changed in at least one of the modes.

5. The high pressure discharge lamp lighting device according to claim 1, wherein in changing power put into the high-pressure discharge lamp, at least two of items of the lighting frequency, the duty ratio and the period in each of the modes are changed, in a case where the changed item is the lighting frequency, the lighting frequency is changed in at least one of the first to third modes, in a case where the changed item is the duty ratio, the duty ratio is changed in at least either the second mode or the third mode, and in a case where the changed item is the period, the period is changed in at least one of the first to third modes.

6. The high pressure discharge lamp lighting device according to any of claims 1 to 5, wherein according to a lamp voltage of a high-pressure discharge lamp, at least one of items of the lighting frequency, the duty ratio and the period in each mode is changed, in a case where the changed item is a lighting frequency, the lighting frequency is changed in at least one of the first to third modes, in a case where the changed item is a duty ratio, the duty ratio is changed in at least either the second mode or the third mode, and in a case where the changed item is the period, the period is changed in at least one of the first to third modes.

7. The high pressure discharge lamp lighting device according to any of claims 1 to 6, wherein a sum of duty ratios in the second and third modes is not made equal to 100% and/or the period of the second mode is made different from the period of the third mode.

8. An image display device comprising the high pressure discharge lamp lighting device according to any of claims 1 to 7.

Fig. 1

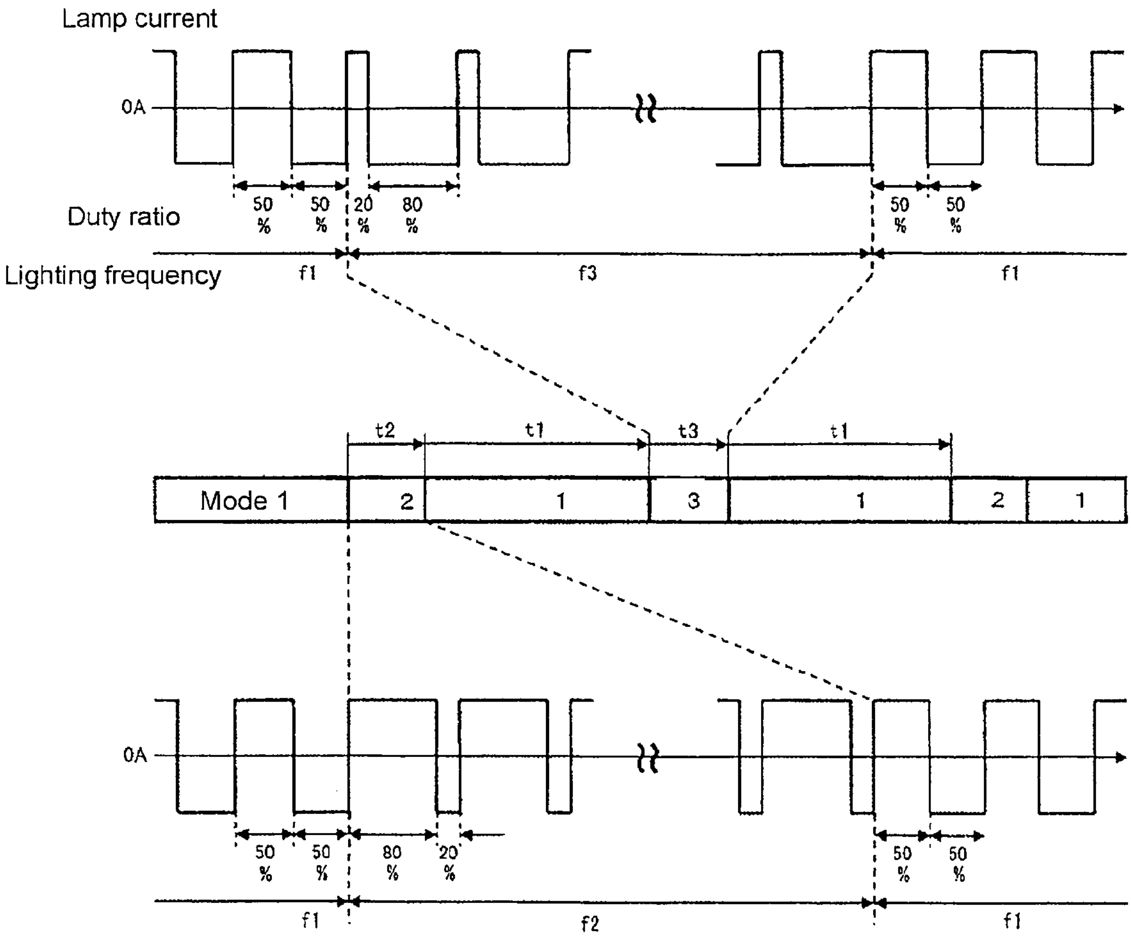
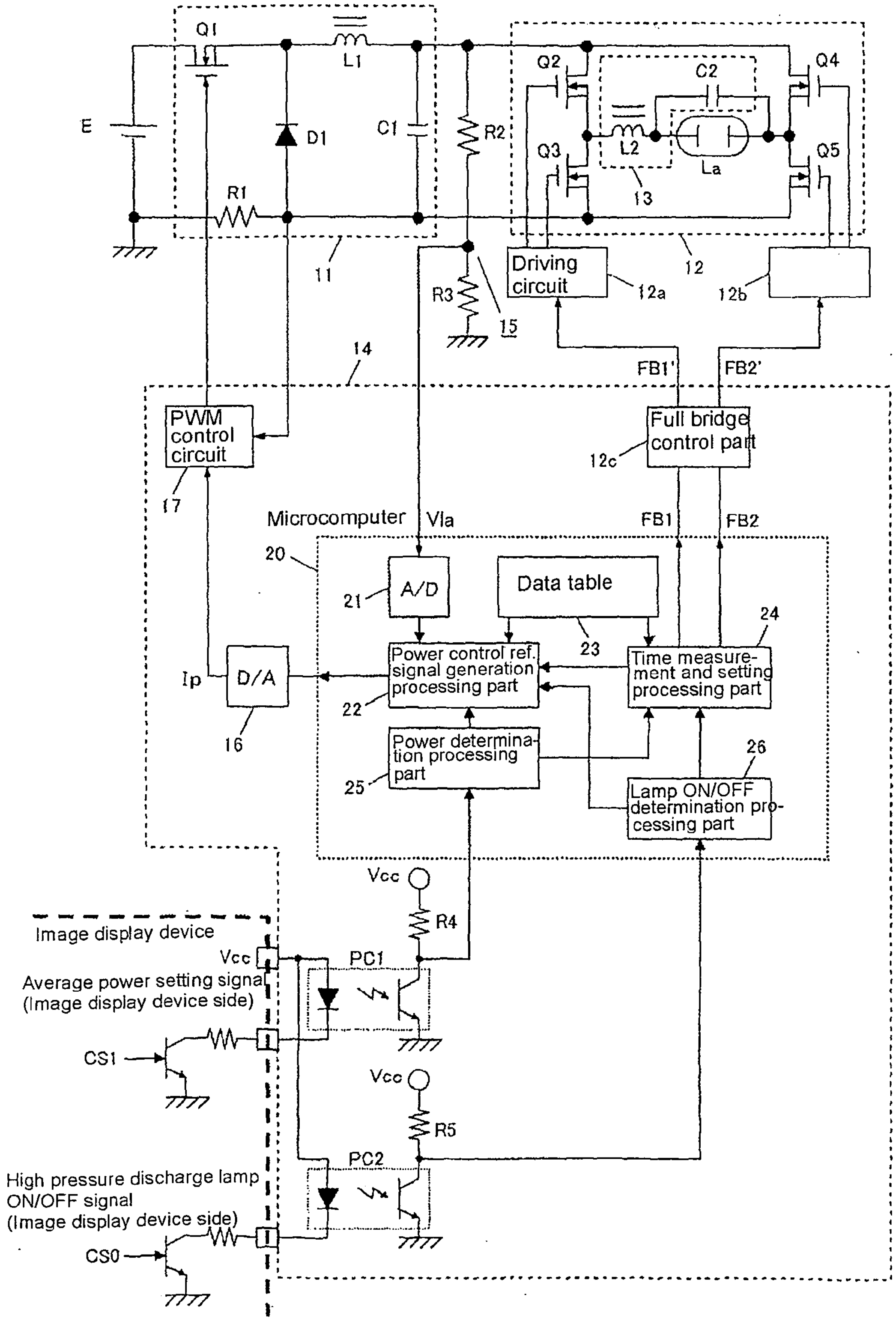

Lamp current
0A
Duty ratio
50 %
50 %
20 %
80 %
50 %
50 %
Lighting frequency
f1
f3
f1
t2
t1
t3
t1
Mode 1
2
1
3
1
2
1
0A
50 %
50 %
80 %
20 %
50 %
50 %
f1
f2
f1

Fig. 2



Q1
L1
E
D1
C1
R2
R1
11
Q2
C2
Q4
L2
La
Q3
Q5
13
12
Driving circuit
12a
12b
R3
15
14
FB1'
FB2'
PWM control circuit
Full bridge control part
12c
17
Microcomputer
Vla
FB1
FB2
20
A/D
Data table
21
24
23
Power control ref. signal generation processing part
Time measurement and setting processing part
Ip
D/A
22
16
Power determination processing part
26
25
Lamp ON/OFF determination processing part
Vcc
R4
Image display device
Vcc
PC1
Average power setting signal (Image display device side)
CS1
Vcc
R5
PC2
High pressure discharge lamp ON/OFF signal (Image display device side)
CS0

Fig. 3

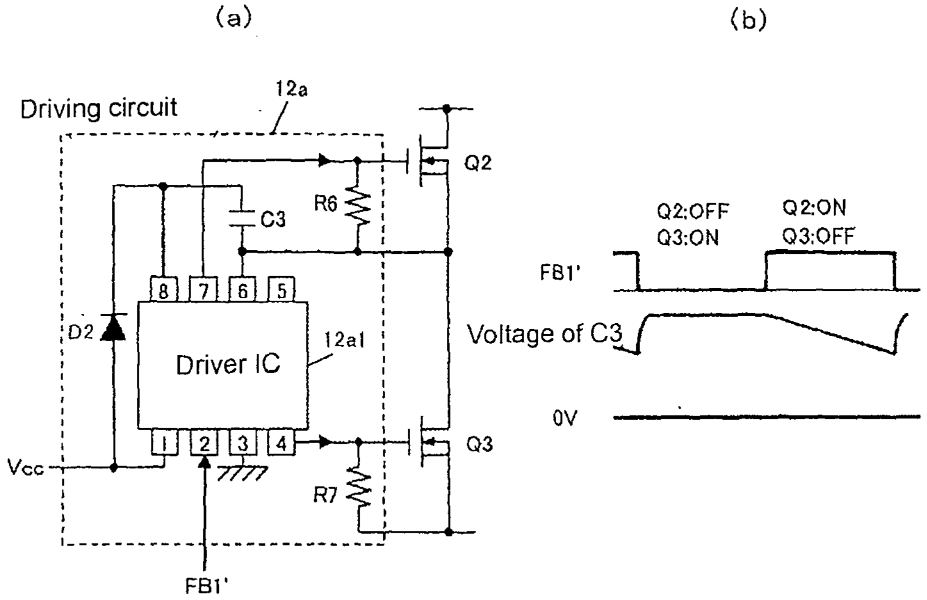

(a)
(b)
Driving circuit
12a
Q2
R6
C3
Q2:OFF
Q3:ON
Q2:ON
Q3:OFF
FB1'
8
7
6
5
D2
Driver IC
12a1
Voltage of C3
0V
1
2
3
4
Q3
Vcc
R7
FB1'

Fig. 4

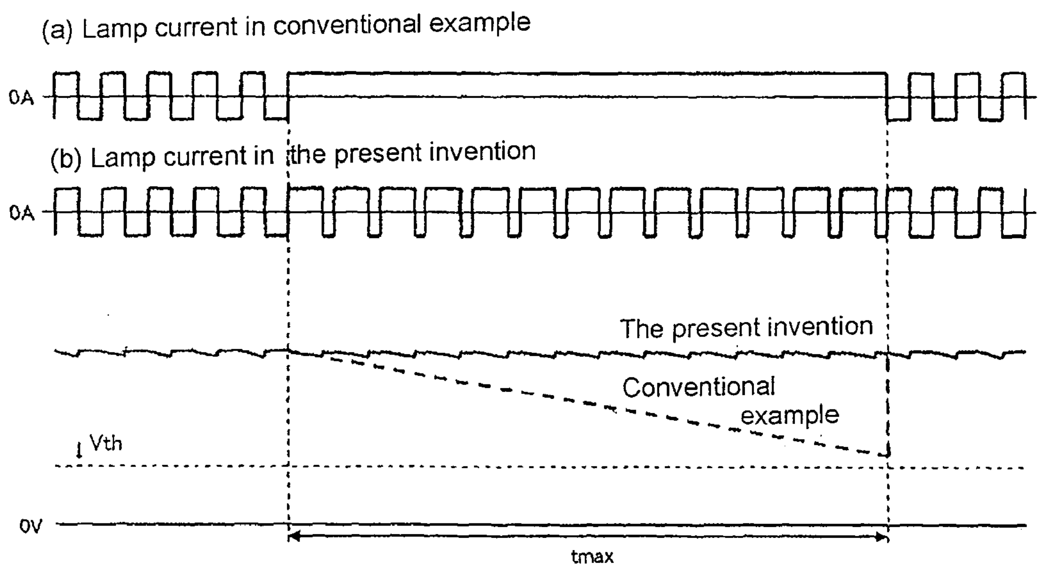

(a) Lamp current in conventional example
0A
(b) Lamp current in the present invention
0A
The present invention
Conventional
example
Vth
0V
tmax

Fig. 5

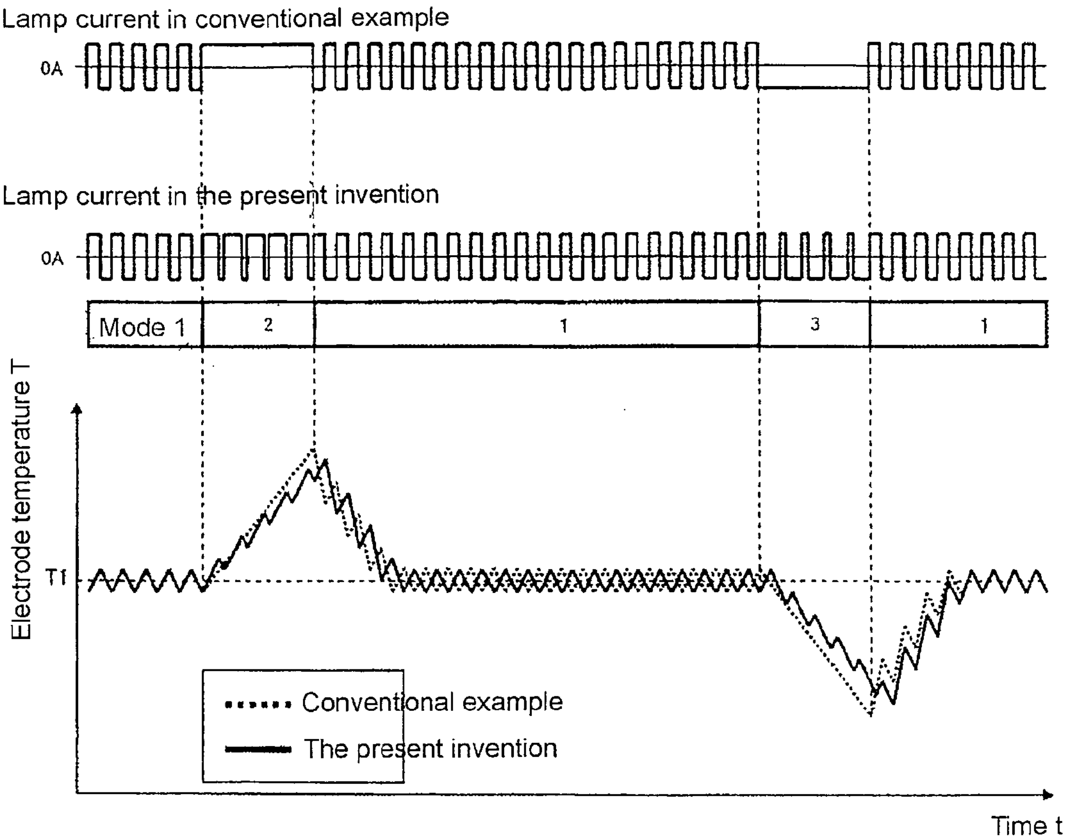

Lamp current in conventional example
0A
Lamp current in the present invention
0A
Mode 1
2
1
3
1
Electrode temperature T
T1
Conventional example
The present invention
Time t

Fig. 6

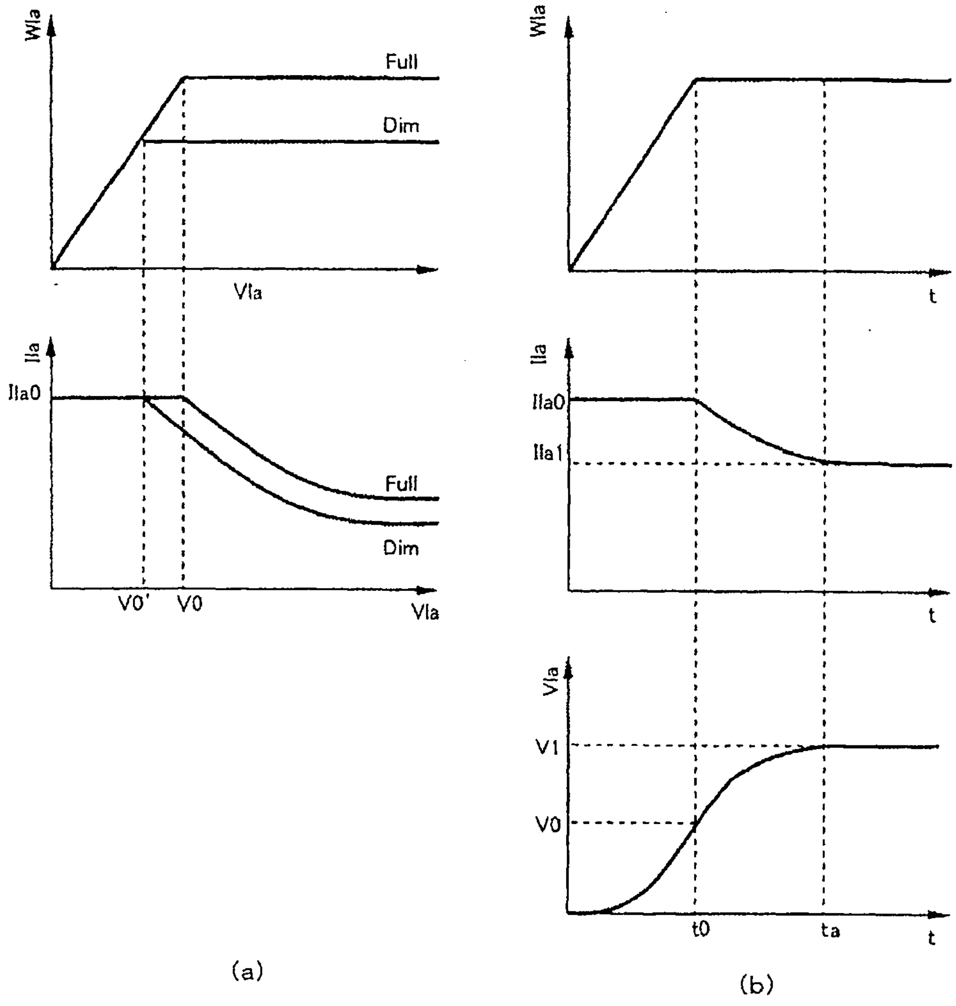

Wla
Full
Dim
Vla
Ila
Ila0
Full
Dim
V0'
V0
Vla
(a)
Wla
t
Ila
Ila0
Ila1
t
Vla
V1
V0
t0
ta
t
(b)

Fig. 7

(a)

Mode	Lightn. freq	Duty ratio	Period
1	f1	=50%	t1
2	f2(≦f1)	>50%	t2
3	f3(≦f1)	<50%	t3

(b1)

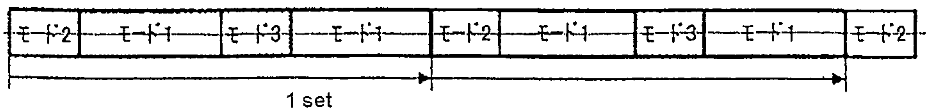


Fig. 8

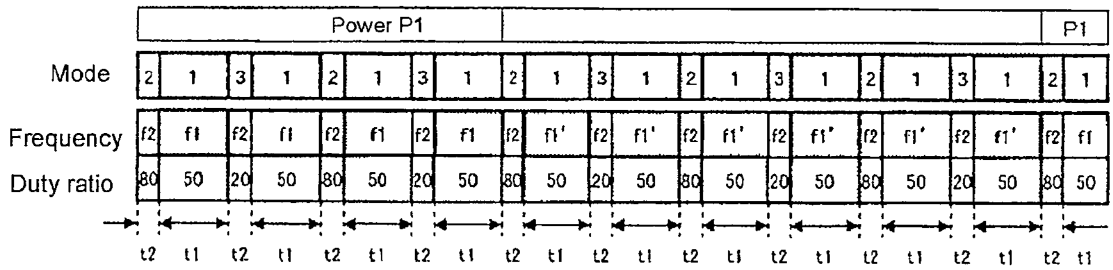


Fig. 9

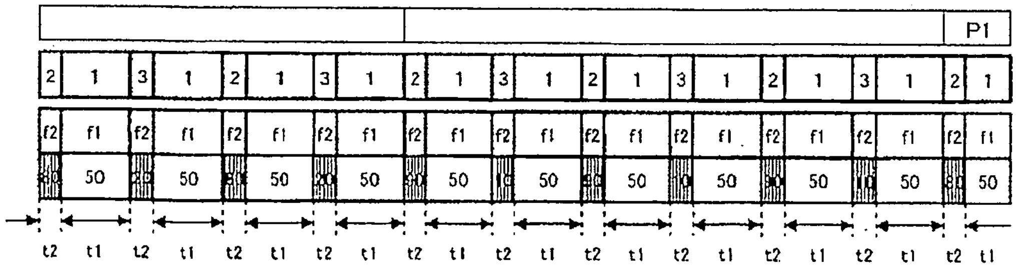


Fig. 10

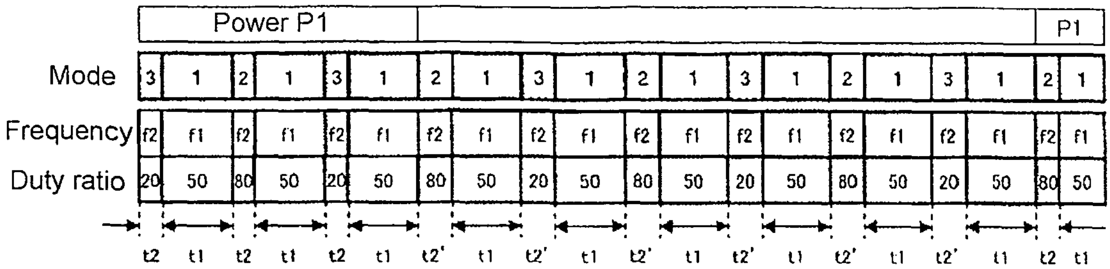


Fig. 11

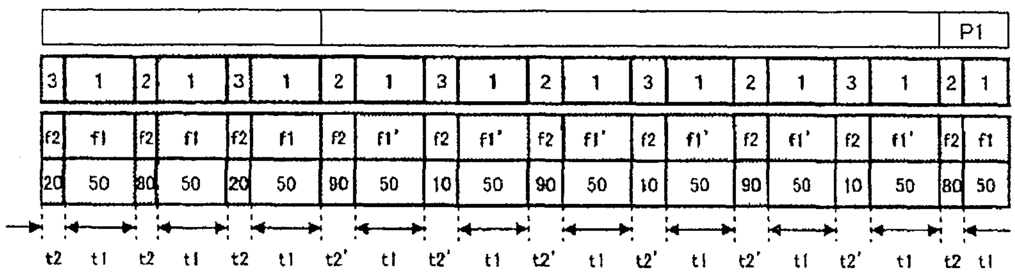


Fig. 12

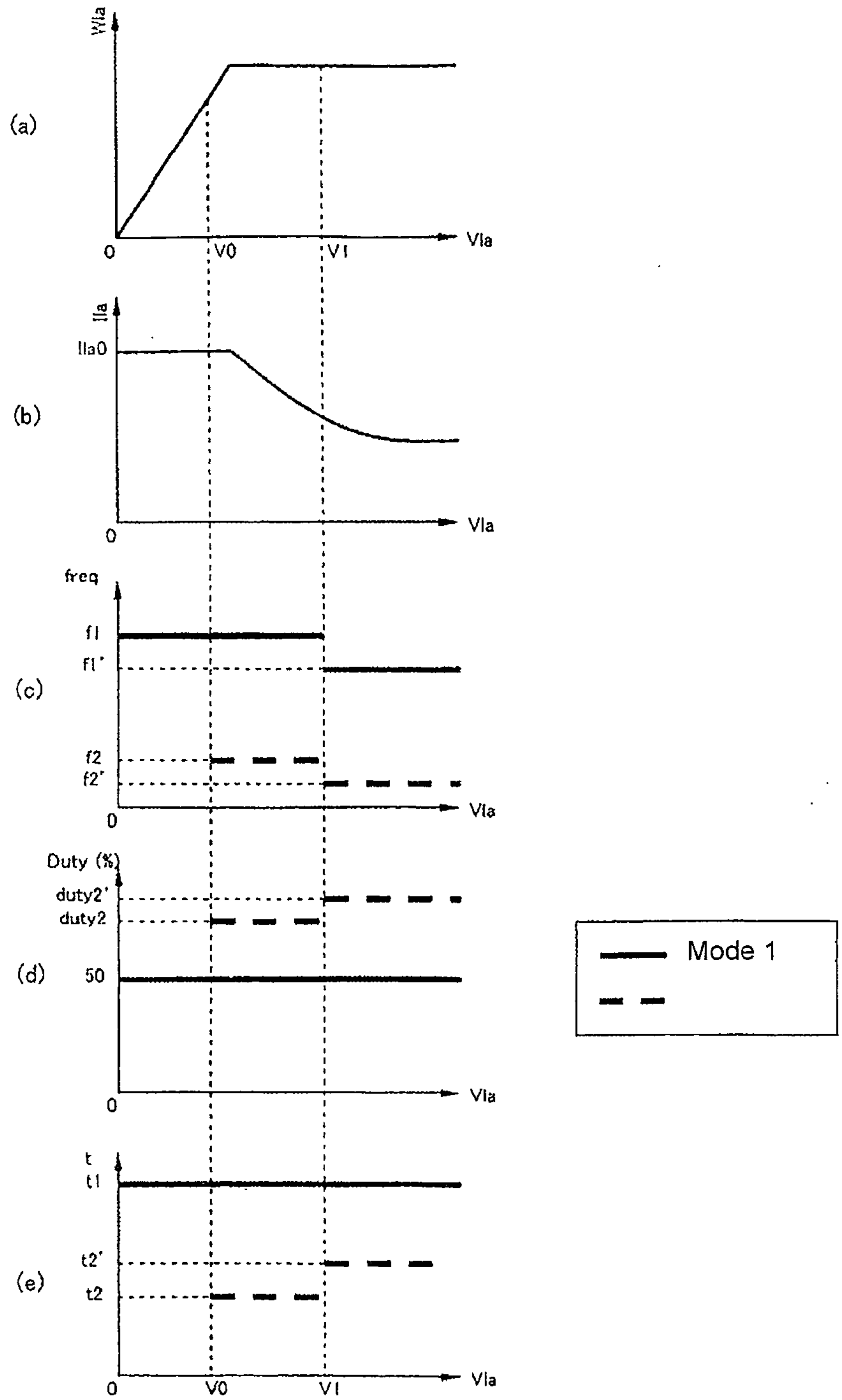

(a)
Wla
0
V0
V1
Vla
(b)
Ila
Ila0
0
Vla
(c)
freq
f1
f1'
f2
f2'
0
Vla
(d)
Duty (%)
duty2'
duty2
50
0
Vla
(e)
t
t1
t2'
t2
0
V0
V1
Vla
Mode 1

Fig. 13

(a)

Mode	Lightn. freq	Duty ratio	Period
1	f1	=50%	t1
2	f2(≦f1)	>50%	t2
3	f2(≦f1)	<50%	t3

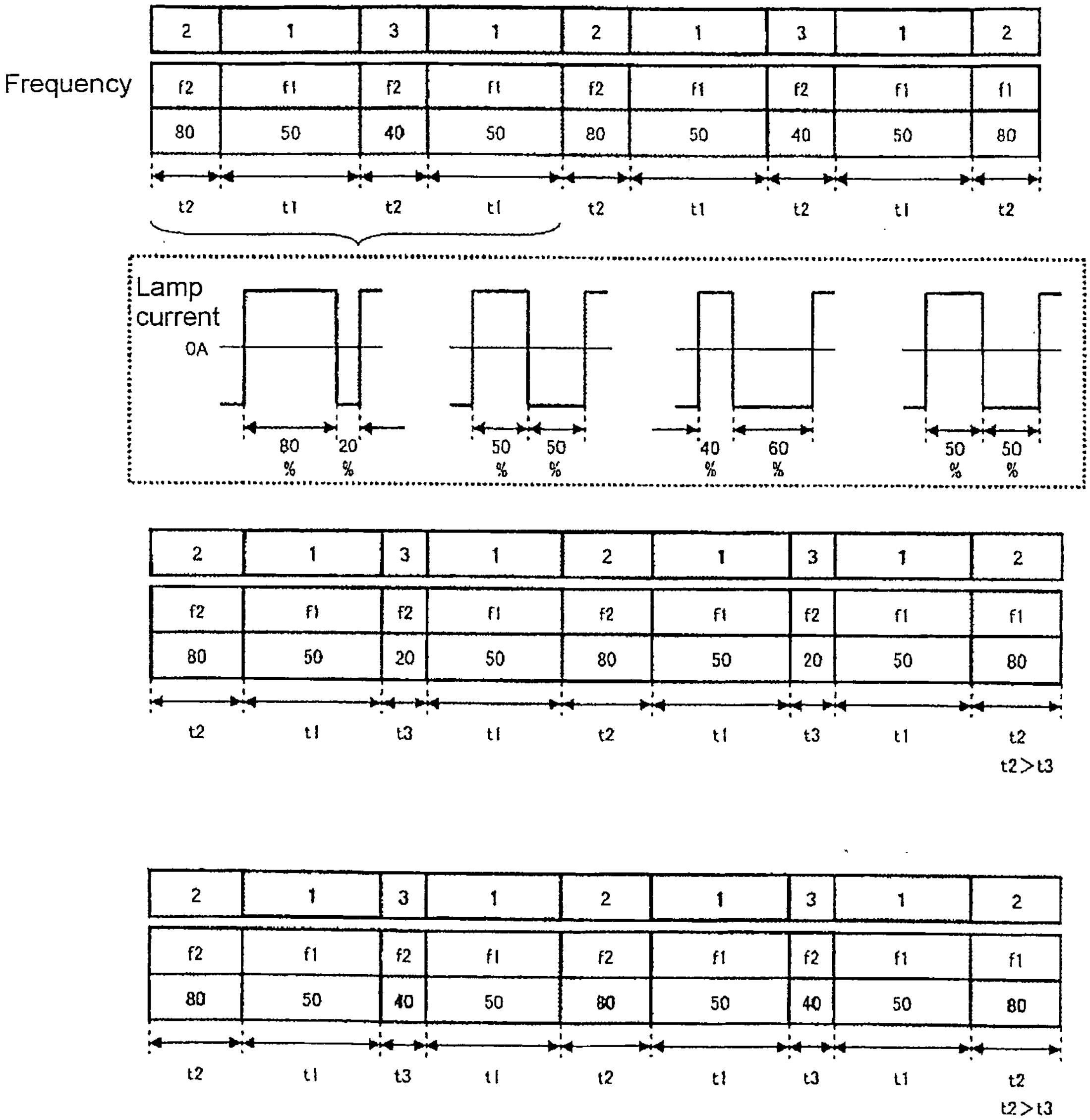


Fig. 14

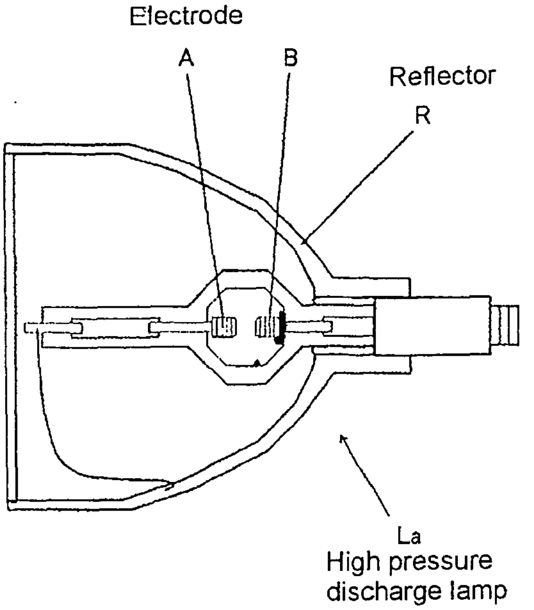
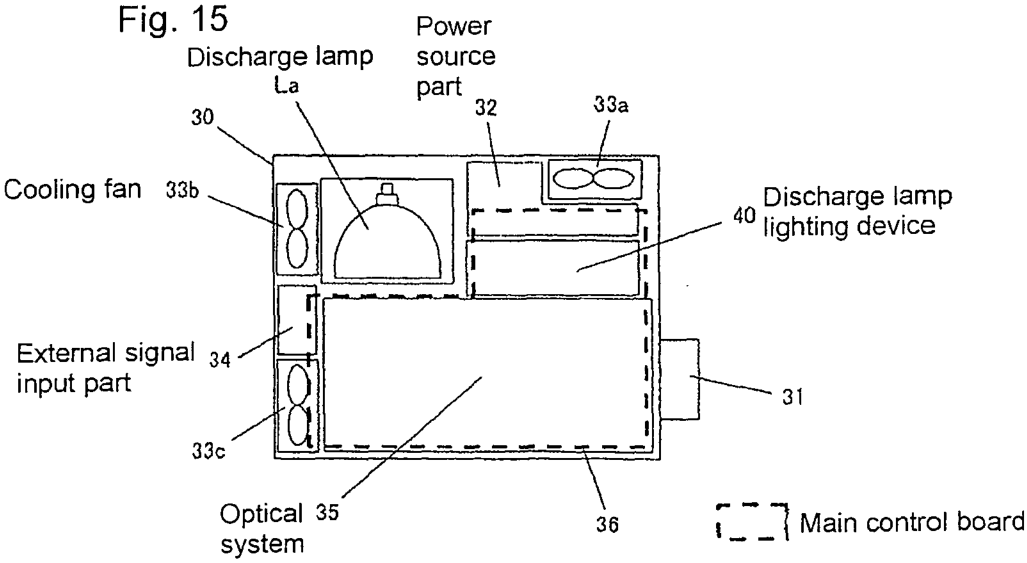

Electrode
A
B
Reflector
R
La
High pressure
discharge lamp

Fig. 15


Discharge lamp
La
Power
source
part
32
33a
30
Cooling fan 33b
40 Discharge lamp
lighting device
External signal
input part
34
31
33c
Optical
system
35
36
Main control board

REFERENCES CITED IN THE DESCRIPTION

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- JP 2001244088 A **[0002] [0006]**
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