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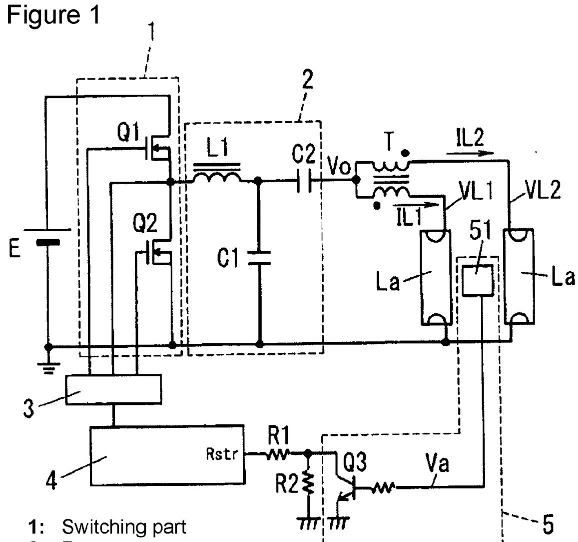
(54) **Discharge lamp lighting device and illumination fixture using the same**

(57) [Object] To provide a discharge lamp lighting device capable of reducing electric stress that is placed on a discharge lamp at the start time, and an illumination fixture using the discharge lamp lighting device.

[Means for Settlement] AC power to which DC power of a DC power source E is converted by an inverter circuit including a switching part 1 and a resonant part 2 is outputted through windings of the balancer T to thereby light a plurality of discharge lamps La. The discharge lamp lighting device is provided with: a drive part 3 that drives respective switching elements Q1 and Q2 constituting the switching part 1; a control part 4 that controls the drive part 3; and a lighting detection part 5 that detects the start of lighting of a part of the plurality of discharge lamps La. When the lighting detection part 5 detects the start of the lighting, the control part 4 controls the drive part 3 so as to sufficiently increase a frequency of the AC power supplied to the respective discharge lamps La through the balancer T to thereby decrease an effective value of the output voltage Vo of the resonant part 4, and thereby electric stress placed on the respective discharge lamps La is reduced.

Figure 1



1: Switching part
2: Resonant part
3: Drive part
4: Control part
5: Lighting detection part
E: DC power source
La: Discharge lamp
T: Balancer

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Description

[Field of the Invention]

[0001] The present invention relates to a discharge lamp lighting device, and an illumination fixture using the same.

[Background Art]

[0002] There has been provided a discharge lamp lighting device that is provided with: a resonant part that constitutes a resonant circuit along with a discharge lamp; and a switching part that lies between a DC power source and the resonant part, includes at least one switching element, and according to on/off of the switching element, switches connection between the DC power source and the resonant part, converts DC power of the above DC power source to AC power on the basis of resonance occurring in the above resonant circuit by operation of the switching part, and lights the discharge lamp with the AC power.

[0003] Further, there is proposed a discharge lamp lighting device that, as illustrated in Fig. 16, uses one switching part 1 to light a plurality of (in the diagram, two) discharge lamps La, in which each of the discharge lamps La is connected to a resonant part 2 through a balancer T (e.g., see Patent literature 1).

[0004] To describe in detail, each of the discharge lamps La is a hot cathode type discharge lamp, and has filaments as a pair of electrodes.

[0005] The switching part 1 includes a series circuit of two switching elements Q1 and Q2 each including an n-channel MOSFET, and is connected between both terminals of a DC power source E. Also, a lower voltage side output terminal of the DC power source E is connected to the ground.

[0006] As the DC power source E, a battery may be used, or a DC power source circuit that converts externally inputted power to DC power having a predetermined voltage may be used. In either case, the DC power source E can be realized by a well known technique, and therefore detailed illustration and description thereof are omitted.

[0007] The balancer T is a so-called balancer transformer having a plurality of windings that are mutually magnetically coupled by, for example, being wound on a common iron core (not illustrated).

[0008] Also, the resonant part 2 is provided with: an inductor L1 of which one terminal is connected to a connecting point between the switching elements Q1 and Q2 of the switching part 1; a first capacitor C1 of which one terminal is connected to the other terminal of the inductor L1 and the other terminal is connected to the ground; and a second capacitor C2 of which one terminal is connected to a connecting point between the inductor L1 and the first capacitor C1 and the other terminal is connected to one terminal of each of the windings of the balancer T. The other terminal of each of the windings of the balancer T is connected to the ground through a corresponding one of the discharge lamps La. That is, the above other terminal of the second capacitor C2 and the above other terminal of the first capacitor C1 respectively serve as output terminals of the resonant part 2, and each of the discharge lamps La are connected between the output terminals of the resonant part 2 as a series circuit with a corresponding one of the windings of the balancer T.

[0009] That is, the switching part 1 and the resonant part 2 constitutes an inverter circuit of a so-called half bridge type, and by alternately on/off driving the switching elements Q1 and Q2 of the switching part 1 (i.e., by periodically driving the respective switching elements Q1 and Q2 so as to always turn off at least one of the switching elements Q1 and Q2, and alternately turn on the two switching elements Q1 and Q2), on the basis of action of a resonant circuit constituted by the resonant part 2 together with the balancer T and each of the discharge lamps La, the DC power of the DC power source E is converted to high frequency AC power, which is then inputted to each of the discharge lamps La.

[0010] The above discharge lamp lighting device is further provided with: a drive part 3 that is connected to gates of the respective switching elements Q1 and Q2 of the switching part 1 to alternately on/off drive the respective switching elements Q1 and Q2; and a control part 4 that controls a frequency (hereinafter referred to as an "operating frequency") of the above on/off driving by the drive part 3. The drive part 3 and control part 4 as described above are respectively realized by well known electric circuits, and therefore detailed illustration and description thereof are omitted.

[0011] Operation of the above control part 4 is described. In a state where any of the discharge lamps La is not lit (hereinafter referred to as an "extinction state"), relationship between an effective value (hereinafter referred to as a "secondary voltage") |Vo| of an output voltage V of the resonant part 2 and an operating frequency f is one as indicated by a curve a in Fig. 17. When the control part 4 starts to light each of the discharge lamps La from the extinction state, the control part 4 performs starting sweep operation that gradually decreases the operating frequency f from an initial frequency fp sufficiently higher than a resonant frequency (hereinafter referred to as an extinction time resonant frequency) fr1 in the extinction state to a predetermined starting frequency fs1 that is higher than the extinction time resonant frequency fr1 and lower than the initial frequency fp. On the basis of this, an operating point gradually changes from a point A1 to a point A2 in Fig. 17, and the secondary voltage |Vo| increases from a predetermined initial voltage Vp to a predetermined starting voltage Vs. Also, after the completion of the starting sweep operation, the control part 4 keeps the operating frequency f at the starting frequency fr1. The above starting voltage Vs is set to a voltage high enough for the discharge lamps La to be able to start lighting (discharging) (i.e., to perform starting).

[0012] Then, in a state where all of the discharge lamps La are lit (hereinafter referred to as a "lighting state"), the relationship between the secondary voltage V and the operating frequency f is one as indicated by a curve c in Fig. 17, and the operating point immediately after the transition to the lighting state is one as indicated by a point C1 in Fig. 17. In the lighting state, the control part 4 changes the operating frequency f according to, for example, a lighting control signal that is externally inputted. On the basis of this, input power to each of the discharge lamps La is changed to thereby change an optical output of each of the discharge lamps La.

[0013] In a state where a lighted discharge lamp La and an unlighted discharge lamp La are mixed (hereinafter referred to as a "semi-lighting state"), the balancer T increases an input voltage to the unlighted discharge lamp La to facilitate the transition to the lighting state, and in the lighting state, reduces an imbalance in input power between the discharge lamps La to average the optical outputs.

[Conventional Technique Literature]

[Patent Literature]

[0014]

[Patent literature 1] JP 2008-218333A

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0015] In the above semi-lighting state, the relationship between the secondary voltage |Vo| and the operating frequency f is, as indicated by a curve b in Fig. 17, one having a resonant frequency fr2 higher than the resonant frequency fr1 of the curve a in the extinction state. As a result, the operating point comes to one indicated by a point B1, and the secondary voltage |Vo| takes a value Vs1 higher than the value Vs in the extinction state, so that excessive electric stress may be placed on the unlighted discharge lamp La. Also, due to the secondary voltage Vs1 as described above, a current flowing through the lighted discharge lamp La is also increased to thereby temporarily increase an optical output at this time, which may cause a user to feel a sense of discomfort.

[0016] The present invention is made for the above reasons, and an object thereof is to provide a discharge lamp lighting device capable of reducing electric stress that is placed on a discharge lamp at the start time, and an illumination fixture using the discharge lamp lighting device.

[Means adapted to solve the Problems]

[0017] A discharge lamp lighting device of the present invention is a discharge lamp lighting device that lights a plurality of discharge lamps, and provided with: a balancer having a plurality of windings each having one terminal connected to one terminal of a corresponding one of the discharge lamps; a resonant part that is connected between both terminals of a series circuit of each of the windings of the balancer and a corresponding one of the discharge lamps, and constitutes a resonant circuit along with the series circuit; a switching part that lies between a DC power source and the resonant part, includes at least one switching element, and according to on/off of the switching element, switches connection between the DC power source and the resonant part; a drive part that on/off drives the respective switching elements of the switching part to supply AC power to the respective discharge lamps from the resonant part through the windings of the balancer; a control part that controls a frequency of operation of the drive part to thereby control a frequency of the AC power outputted to the respective discharge lamps; and a lighting detection part that detects a start of lighting of a part of the plurality of discharge lamps, wherein when the lighting detection part detects the start of the lighting, the control part increases the frequency of the operation of the drive part, and an amount of the increase of the frequency is set to be large enough to make an effective value of an output voltage of the resonant part lower than an effective value for a case where the frequency is not changed.

[0018] Also, preferably, the discharge lamp lighting device is provided with a capacitor having both terminals that are respectively connected to a connecting point between one of the windings of the balancer and a corresponding one of the discharge lamps and a connecting point between the other winding and the other discharge lamp.

[0019] Further, preferably, the discharge lamp lighting device is provided with an extinction detection part that detects start of an extinction state where all of the discharge lamps are extinguished, wherein after a predetermined delay time has passed since the extinction detection part detected the start of the extinction state, the control part decreases the frequency of the operation of the drive part to a frequency before the lighting detection part detects the start of a semi-lighting state.

[0020] Also, preferably, in the discharge lamp lighting device, the balancer has a detecting winding, and when an effective value of an inter-terminal voltage of the detecting winding exceeds a predetermined lighting determination voltage, the lighting detection part detects the start of the semi-lighting state.

[0021] Further, preferably, in the discharge lamp lighting device, when the effective value of the inter-terminal voltage of the detecting winding falls below a predetermined extinction determination voltage, the control part decreases the frequency of the operation of the drive part, and the extinction determination voltage is set to be lower than the lighting determination voltage.

[0022] Also, preferably, in the discharge lamp lighting device, as a difference between the effective value of the inter-terminal voltage of the detecting winding and the lighting determination voltage increases, the control part more increases the frequency of the operation of the drive part.

[0023] Further, preferably, in the discharge lamp lighting device, when an effective value of an input current from a side of the discharge lamps to the resonant part exceeds a predetermined lighting determination current, the lighting detection part detects the start of the semi-lighting state.

[0024] Preferably, an illumination fixture of the present invention is provided with: any of the above-described discharge lamp lighting devices; and a fixture main body that holds the discharge lamp lighting device.

[Effect of the Invention]

[0025] When the start of the lighting is detected, the frequency of the operation of the drive part that drives the respective switching elements of the switching part is increased to thereby decrease the effective value of the output voltage of the resonant part, and therefore as compared with the case where the frequency of the operation of the drive part is not increased, electric stress placed on a discharge lamp at the start time can be reduced.

[Brief Description of the Drawings]

[0026]

[Fig. 1] Fig. 1 is a circuit block diagram illustrating a first embodiment of the present invention.

[Fig. 2] Fig. 2 is an explanatory diagram illustrating relationship between the operating frequency f and an effective value |Vo| of the output voltage Vo of a resonant part in the first embodiment.

[Fig. 3] Fig. 3 is an explanatory diagram illustrating operation of the first embodiment in the case where the number of discharge lamps is two, in which time variations of an inter-terminal voltage VL1 and a current value IL1 of a first lighted discharge lamp, an inter-terminal voltage VL2 and a current value IL2 of a subsequently lighted discharge lamp, and a detection voltage Va, and the operating frequency f are illustrated.

[Fig. 4] Fig. 4 is a circuit block diagram illustrating a variation of the first embodiment.

[Fig. 5] Fig. 5 is an explanatory diagram illustrating operation of the variation of Fig. 4 in the case where the number of discharge lamps is two, in which time variations of the inter-terminal voltage VL1 and the current value IL1 of a first lighted discharge lamp, the inter-terminal voltage VL2 and the current value IL2 of a subsequently lighted discharge lamp, and the detection voltage Va, and the operating frequency f are illustrated.

[Fig. 6] Fig. 6 is a circuit block diagram illustrating a second embodiment of the present invention.

[Fig. 7] Fig. 7 is an explanatory diagram illustrating operation of the second embodiment in the case where the number of discharge lamps is two, in which time variations of the inter-terminal voltage VL1 and the current value IL1 of a first lighted discharge lamp, the inter-terminal voltage VL2 and the current value IL2 of a subsequently lighted discharge lamp, and the detection voltage Va, and the operating frequency f are illustrated.

[Fig. 8] Fig. 8 is a circuit block diagram illustrating a third embodiment of the present invention.

[Fig. 9] Fig. 9 is an explanatory diagram illustrating operation of the third embodiment in the case where the number of discharge lamps is two, in which time variations of the inter-terminal voltage VL1 and the current value IL1 of a first lighted discharge lamp, the inter-terminal voltage VL2 and the current value IL2 of a subsequently lighted discharge lamp, and the detection voltage Va, and the operating frequency f are illustrated.

[Fig. 10] Fig. 10 is a circuit block diagram illustrating a fourth embodiment of the present invention.

[Fig. 11] Fig. 11 is an explanatory diagram illustrating operation of the fourth embodiment in the case where the number of discharge lamps is two, in which time variations of the inter-terminal voltage VL1 and the current value IL1 of a first lighted discharge lamp, the inter-terminal voltage VL2 and the current value IL2 of a subsequently lighted discharge lamp, and the detection voltage Va and a threshold voltage Vth, an on/off state of a transistor Q3, and the operating frequency f are illustrated.

[Fig. 12] Fig. 12 is a circuit block diagram illustrating a variation of the fourth embodiment.

[Fig. 13] Fig. 13 is a circuit block diagram illustrating another variation of the fourth embodiment.

[Fig. 14] Fig. 14 is a circuit block diagram illustrating still another variation of the fourth embodiment.

[Fig. 15] Fig. 15 is a perspective view illustrating an example of an illumination fixture using any of the embodiments.

[Fig. 16] Fig. 16 is a circuit block diagram illustrating a conventional example.

[Fig. 17] Fig. 17 is an explanatory diagram illustrating relationship between the operating frequency f and the effective value |Vo| of the output voltage Vo of a resonant part in the conventional example.

[Best Modes for Carrying Out the Invention]

[0027] Best modes for carrying out the present invention will hereinafter described referring to the drawings.

[0028] Note that, in the following, the case where the number of discharge lamps La to be lit is two is cited as an example; however, if a series circuit of a winding of the balancer T and a discharge lamp La is appropriately added, a configuration where three or more discharge lamps La are lit can also be provided.

(First embodiment)

[0029] A basic configuration of the present embodiment is in common with the conventional example described with Fig. 16, and therefore description of common parts is omitted.

[0030] In the present embodiment, as illustrated in Fig. 1, the control part 4 is connected to the ground through a series circuit of two resistors R1 and R2; has a control terminal Rstr that is, after at least the completion of the starting sweep operation, kept at a constant voltage; and controls the drive part 3 so as to increase the operating frequency f as a current flowing out of the control terminal Rstr increases. That is, as an impedance between the above control terminal Rstr and the ground decreases, the operating frequency f is increased.

[0031] Also, in the present invention, there is provided a lighting detection part 5 that detects lighting of at least one of the discharge lamps La. The lighting detection part 5 in the present embodiment is provided with: an optical sensor 51 that outputs the detection voltage Va depending on a lighting situation of the discharge lamps La; and an npn type transistor Q3 having a base that is inputted with the detection voltage Va through a resistor. The above optical sensor 51 outputs an output voltage (hereinafter referred to as the "detection voltage") Va as an H level during a period during which at least one of the discharge lamps La is lit, or as an L level during a period during which all of the discharge lamps La is extinguished. Such an optical sensor 51 can be realized by a well known technique using a light sensitive element such as a photodiode, and therefore detailed illustration and description thereof are omitted. The above transistor Q3 has a collector connected to a connecting point between the above resistors R1 and R2 and an emitter connected to the ground.

[0032] That is, during the period during which the detection voltage Va is at an H level (i.e., during the period during which the lighting of at least one of the discharge lamps La is detected), the transistor Q3 is turned on to thereby increase the operating frequency f. That is, immediately after the detection voltage Va turns from an L level to an H level, the lighting situation is considered as the semi-lighting state where only one of the discharge lamps La is lit.

[0033] In the following, with use of Figs. 2 and 3, operation of the present embodiment is described. Note that, in Fig. 3, horizontal axes all represent time, and vertical axes represent, sequentially from top, the inter-terminal voltage VL1 of one of the discharge lamps La, the current IL1 flowing through the one discharge lamp La, the inter-terminal voltage VL2 of the other discharge lamp La, the current IL2 flowing through the other discharge lamp La, the detection voltage Va, and the operating frequency f.

[0034] When the control part 4 starts to light the discharge lamps La, as with the conventional example, the control part 4 performs the starting sweep operation that gradually decreases the operation frequency f from the initial frequency fp sufficiently higher than the extinction time resonant frequency fr1 to the predetermined starting frequency fs1 higher than the extinction time resonant frequency fr1 and lower than the initial frequency fp with taking a predetermined time (from t1 to t2 in Fig. 3).

[0035] Also, after the completion of the starting sweep operation, the control part 4 keeps the operating frequency f at the starting frequency fs1 from timing when the lighting of at least one of the discharge lamps La is detected in the lighting detection part 5 to timing t4 when the detection voltage Va turns to an H level.

[0036] Further, at the timing t4 immediately after the timing t3 when one of the discharge lamps La is lit, when in the lighting detection part 5, the lighting of the discharge lamp La is detected, and the detection voltage Va turns to an H level to turn on the transistor Q3 (i.e., when the start of the semi-lighting state is detected), the control part 4 changes the operating frequency f to a second starting frequency fs2 higher than the starting frequency fs1. The second starting frequency fs2 is set to the operating frequency f that is higher than the resonant frequency in the semi-lighting state (hereinafter referred to as a "semi-lighting time resonant frequency") fr2 and meets a secondary voltage Vs2 that is lower than the secondary voltage Vs1 for the case where the operating frequency f is kept at the starting frequency fs1 (i.e., the secondary voltage at an operating point B1 in Fig. 2). On the basis of this, the operating point moves to one indicated by a point B2 in Fig. 2, and then when the lighting situation transitions to the lighting state, the operating point moves to one indicated by a point C2

[0037] Further, there may be provided a configuration where lighting completion detecting means (not illustrated) adapted to detect the start of the lighting state is provided, and also after the start of the lighting state has been detected by the lighting completion detecting means, the control part 4 controls the drive part 3 according to an externally inputted light control signal, or if the start of the lighting state is not detected even after a predetermined period has passed since the start of operation, the control part 4 stops operation of the drive part 3 to respectively keep the switching elements Q1 and Q2 in the switching part 1 in off states. The lighting completion detecting means as described above can be realized by a well known technique, and therefore illustration and description thereof are omitted.

[0038] According the above configuration, as compared with the case where when the start of the semi-lighting state is detected, the operating frequency f is not changed, at the start time of the semi-lighting state, the secondary voltage |Vo| is suppressed, and thereby electric stress placed on each of the discharge lamps La is reduced. At the same time, a current flowing through a first lighted discharge lamp La is also suppressed, and therefore a sense of discomfort due to the temporary increase in optical output is unlikely to be provided to a user.

[0039] In addition, the lighting detection part 5 may be adapted to use, in place of the detection voltage Va outputted by the optical sensor 51 as described above, the detection voltage Va obtained by, as illustrated in Fig. 4, half-wave rectifying an input current from the discharge lamp La side to the resonant part 2 (i.e., a current formed by combining the currents IL1 and IL2 flowing through all of the discharge lamps La) IL1+IL2 to obtain a current; converting the current with a resistor; and smoothing the converted current with a capacitor. In this case, as illustrated in Fig. 5, at t4 when the above detection voltage Va reaches a base-emitter voltage (hereinafter referred to as an "on voltage") Vbe necessary to turn on the transistor Q3, the transistor Q3 is turned on to increase the operating frequency f. That is, a current obtained by dividing the on voltage Vbe of the transistor Q3 by a ratio of the detection voltage Va to an effective value of the above input current IL1+IL2 is a lighting determination current.

[0040] Note that, in any of the examples of Figs. 1 and 4, when the lighting situation transitions from the semi-lighting state to the extinction state due to fading away of the discharge lamp La, the operating frequency f immediately returns to the starting frequency fs1. Accordingly, if the transition between the extinction state and the semi-lighting state frequently occurs, the operating frequency f is also frequently switched, and thereby an amplitude of the secondary voltage Vo becomes unstable, which may place excessive electric stress on the respective discharge lamps La and the respective circuit components. For this reason, there may be provided a configuration where in a stage prior to a gate of the transistor Q3, an appropriate delay circuit (not illustrated) is inserted; until a lowering state of the detection voltage Va, which is determined to be the extinction state, continues for a predetermined delay time, the operating frequency f is kept at the second starting frequency fs2 without change; and if the lowering state of the detection voltage Va continues for the above delay time, the operating frequency f is returned to the starting frequency fs1. In the case of employing this configuration, while avoiding the excessive electric stress as described above, if a duration time of the extinction state becomes equal to or more than the above delay time, the operating frequency f is returned to the starting frequency fs1, and thereby restart can be performed. In any of the examples of Figs. 1 and 4, in the case of employing the above configuration, a circuit that generates the detection voltage Va (in the example of Fig. 1, the optical sensor 51) serves as an extinction detection part, and falling of the detection voltage Va below the on voltage Vbe of the transistor Q3 means the detection of start of the extinction state.

(Second embodiment)

[0041] A basic configuration of the present embodiment is in common with the first embodiment, and therefore description of common parts is omitted.

[0042] In the present embodiment, as illustrated in Fig. 6, in the balancer T, there is provided a detecting winding that is, with respect to the other windings respectively connected to the discharge lamps La, magnetically coupled by, for example, being wound on the common iron core.

[0043] Also, the lighting detection part 5 of the present embodiment is one that, instead of using the optical sensor 51, half-wave rectifies and smoothes an inter-terminal voltage of the above detection winding to thereby generate the detection voltage Va that is a voltage proportional to an effective value of the inter-terminal voltage of the detection winding. Also, the detection voltage Va is connected to the base of the transistor Q3 through a zener diode ZD and a resistor. That is, only during a period during which the above detection voltage Va exceeds a sum of a zener voltage VZD of the zener diode ZD and the on voltage Vbe of the transistor Q3 (hereinafter referred to as a "reference voltage") VZD+Vbe, the transistor Q3 is turned on to increase the operating frequency f. In other wards, a voltage obtained by dividing the above reference voltage VZD+Vbe by a ratio of the detection voltage Va to the effective value of the inter-terminal voltage of the detection winding (hereinafter referred to as a "detection ratio") is the lighting determination voltage. The above zener voltage VZD is determined such that when the lighting situation at least transitions from the extinction state to the semi-lighting state, the transistor Q3 is turned on. That is, even in the present embodiment, switching of the transistor Q3 from an off state to an on state means the detection of start of the semi-lighting state.

[0044] As illustrated in Fig. 7, the detection voltage Va in the present embodiment takes a value of substantially 0 V in the extinction or lighting state, and in the semi-lighting state, takes a value higher than that in the extinction or lighting state. Also, in the present embodiment, each of the circuit components is selected such that only in the semi-lighting state, the transistor Q3 is turned on. That is, in the present embodiment, by an amount equal to an increase in the operating frequency f at t4 immediately after the transition from the extinction state to the semi-lighting state, the operating frequency f is decreased at f6 immediately after the transition from the semi-lighting state to the lighting state.

[0045] In addition, if an appropriate latch circuit (not illustrated) that after the transistor Q3 has been brought into the on state, regardless of the detection voltage Va, keeps the on state of the transistor Q3 is added, a variation in optical power of the discharge lamps La at t6 immediately after the transition from the semi-lighting state to the lighting state can be prevented. The latch circuit as described above can be realized by a well known technique using, for example, an RS flip-flop circuit, and therefore illustration and description thereof is omitted.

(Third embodiment)

[0046] A basic configuration of the present embodiment is in common with the second embodiment, and therefore description of common parts is omitted.

[0047] In the present embodiment, instead of using the transistor Q3, as illustrated in Fig. 8, an inverting amplifier circuit configured with use of an operational amplifier OP is used. That is, in the above operating amplifier OP, an inverting input terminal is inputted with the detection voltage Va through a resistor; a non-inverting input terminal is inputted with a predetermined reference voltage Vref1; an output terminal and the inverting input terminal are connected to each other through a capacitor; and the output terminal is connected to the control terminal Rstr of the control part 4 through a diode having a cathode facing to the operational amplifier OP and a resistor R4. Also, the control terminal Rstr of the control part 4 is connected to the ground through a resistor R3 having a resistance value equivalent to that of the series circuit of the resistors R1 and R2 in the first or second embodiment. That is, if the detection voltage Va exceeds the reference voltage Vref1, the output terminal of the operational amplifier is brought to a negative voltage, which means the detection of the semi-lighting state, and the reference voltage Vref1 is, in other words, the lighting determination voltage.

[0048] In the case where a plurality of types of discharge lamps La having mutually different rated powers (i.e., mutually different impedances) can be connected, in the semi-lighting state, the lower the impedance of the already lighted discharge lamp La, the more likely the inter-terminal voltage VL2 of the unlighted discharge lamp La is to increase.

[0049] On the other hand, in the present embodiment, as illustrated in Fig. 9, as a difference between an effective value of the inter-terminal voltage VL1 of the already lighted discharge lamp La and an effective value of the inter-terminal voltage VL2 of the unlighted discharge lamp La increases, a difference between the detection voltage Va and the reference voltage Vref1 as the lighting determination voltage is increased, so that the voltage of the output terminal of the operational amplifier OP is decreased to increase the current flowing out of the control terminal Rstr of the control part 4, and thereby the operating frequency f is increased.

[0050] That is, in the semi-lighting state, the lower the impedance of the already lighted discharge lamp La, the more the operating frequency f is increased, and therefore the inter-terminal voltage VL2 of the unlighted discharge lamp La is suppressed.

(Fourth embodiment)

[0051] A basic configuration of the present embodiment is in common with the second embodiment, and therefore description of common parts is omitted.

[0052] In the present embodiment, as illustrated in Fig. 10, there is provided a comparator CP of which an non-inverting input terminal is inputted with the detection voltage Va; an inverting input terminal is inputted with the threshold voltage Vth into which a predetermined control voltage Vcc is divided by a resistor; and an output terminal is connected to the base of the transistor Q3 through a resistor.

[0053] Also, out of the resistors making the division into the above threshold voltage Vth, a lower voltage side resistor is connected in parallel with a series circuit of an npn type transistor (hereinafter referred to as a "threshold value changing transistor") Q4 having a base connected to the output terminal of the comparator CP and a resistor. That is, during a period during which an output of the comparator CP is at an H level, the threshold value changing transistor Q4 is turned on to thereby, as illustrated in Fig. 11, change the threshold voltage Vth to a threshold voltage (hereinafter referred to as an "extinction determination voltage") Vth2 lower than a threshold voltage (hereinafter referred to as a "lighting determination voltage") Vth1 during a period during which the output of the comparator CP is at an L level. In other words, when during a period during which the transistor Q3 is in the off state, the detection voltage Va increases to reach the lighting determination voltage Vth1, the transistor Q3 is turned on, whereas when during a period during which the transistor Q3 is in the on state, the detection voltage Va decreases to reach the extinction determination voltage Vth, the transistor Q3 is turned off.

[0054] Further, a parallel circuit of the transistor Q3 and the resistor R2 is connected in parallel with a capacitor (hereinafter referred to as a "capacitor for time constant") C4. By a time constant of the capacitor for time constant C4, immediately after the transistor Q3 is turned off, the operating frequency f is gradually decreased to the starting frequency fs1.

[0055] According to the above configuration, a time from timing when after the lighting detection part 5 has detected the start of the lighting (i.e., the transistor Q3 has been turned on), the detection voltage Va decreases and no longer meets an on condition for the transistor Q3 (i.e., the detection voltage Va falls below the lighting determination voltage Vth1) to timing when the transistor Q3 is turned off and the control part 4 decreases the operating frequency f is longer than that in the second embodiment. Also, even if in a first lighted one of the discharge lamps La, instantaneous fading away occurs, and the detection voltage Va reaches the lighting determination voltage Vth1, as long as the detection voltage Va does not reaches the extinction determination voltage Vth2 lower than Vth1, the operating frequency f is not decreased to the starting frequency fs1 but kept at the second starting frequency fs2. On the basis of this, as compared with the case where the threshold voltage Vth is not changed, electric stress that is, if the transition from the semi-lighting state to the extinction state due to the fading away is repeated, placed on the respective discharge lamps La and respective circuit components is reduced. Also, when the detection voltage Va decreases to the extinction determination voltage Vth2, the operating frequency f is returned to the starting frequency fs1, and therefore differently from the case where the operating frequency f is not returned to the starting frequency fs1, even if the lighting situation transitions from the semi-lighting state to the extinction state due to the occurrence of the fading away, restart can be performed.

[0056] Note that, instead of employing the configuration in which the threshold voltage Vth changes as described above, even in the case where an appropriate delay circuit that after a predetermined delay time since the output of the comparator Cp changed from an H level to an L level, turns off the transistor Q3 is inserted between the comparator CP and the transistor Q3, the same effect is obtained. The delay circuit as described above can be realized by a well known technique, and therefore detailed description and illustration thereof are omitted.

[0057] Meanwhile, if an inductance of the balancer T is increased, a difference in optical output between the discharge lamps La in the lighting state can be further decreased; however, a voltage applied to the unlighted discharge lamp La in the semi-lighting state is also increased. For this reason, as with Patent literature 1, in each of the above embodiments, as illustrated in Fig. 12, a capacitor C3 of which both terminals are respectively connected to a connecting point between one of the windings of the balancer T and a corresponding one of the discharge lamps La and a connecting point between the other winding and the other discharge lamp La may be added. If this configuration is employed, without excessively increasing the inductance of the balancer T, the difference in an optical output between the discharge lamps La in the lighting state can be decreased. In the case where, as in Fig. 1, the above capacitor C3 is not provided, in the semi-lighting state, a current does not flow through the unlighted discharge lamp La and the winding of the balancer T, which is connected to the unlighted discharge lamp La, and thereby the resonant part 2 constitutes a resonant circuit along with a series circuit of the lighted discharge lamp La and the corresponding winding of the balancer T. On the other hand, in the case where the above capacitor C3 is provided, a resonant circuit constituted in the semi-lighting state is configured such that in the above resonant circuit, a series circuit of the winding connected to the unlighted discharge lamp La out of the windings of the balancer T and the above capacitor C3 is connected in parallel to the winding connected to the lighted discharge lamp La out of the windings of the balancer T. Also, in the above case, as also described in Patent literature 1, it is preferable to determine a capacitance value of the capacitor 3 such that an envisaged maximum value fdim of the operating frequency f, and a parallel resonant frequency f0 between the inductance of the balancer T and the above capacitor C3 meets $0.8 \times \mathrm{fdim} \leq \mathrm{f0} \leq 1.6 \times \mathrm{fdim}$.

[0058] Further, instead of, in the resonant part 2, providing the second capacitor C2 between the inductor L1 and the respective windings of the balancer T, as illustrated in Fig. 13 or 14, between the respective windings of the balancer T and the corresponding discharge lamps La, capacitors C2a and C2b each having a capacitance corresponding to the equally divided (in the case of each of the diagrams, divided into two equal parts) second capacitor C2 may be inserted.

[0059] Note that each of Figs. 12 to 14 illustrates the case of applying variations to the example of Fig. 1 in the first embodiment; however, the example of Fig. 4 in the first embodiment, or any of the second to fourth embodiments can also be applied with the same variations.

[0060] Note that a circuit configuration is not limited to any of the above ones, but for example, a single transistor type inverter circuit in which a switching part 1 includes one switching element may be used. Alternatively, there may be used an inverter circuit of a so-called full bridge type that has: a switching part 1 in which two series circuits each including two switching elements are connected in parallel; and a resonant part 2 connected between connecting points between the switching elements of one of the series circuits and between the switching elements of the other series circuit. Further, the control part 4 and lighting detection part 5 may also be configured such that the control part 4 is directly inputted with an output of the lighting detection part 5 to switch the operating frequency f according to the output. Variations as described above can be realized by a well know technique, and therefore detailed illustration and description thereof are omitted.

[0061] Any of the above-described various types of discharge lamp lighting devices can be used for an illumination fixture 6 as illustrated in Fig. 15. To describe in detail, the illumination fixture 6 in Fig. 15 is provided with: a rectangular parallelepiped shaped fixture main body 61 that contains and holds the respective circuit components constituting the discharge lamp lighting device, such as the switching part 1, the resonant part 2, and the balancer T; and four sockets 62 each of which is electrically connected to a corresponding one of the output terminals of the resonant part 2 directly or through a corresponding one of the windings of the balancer T, held on one surface side of the fixture main body 61, and electrically and mechanically connected to a corresponding one of terminals of a corresponding one of the discharge lamps La of a straight tube type. In the fixture main body 61, the surface holding the respective sockets 62 (i.e., a surface on a side where the respective discharge lamps La are arranged, and a lower surface in Fig. 15) diffusely or fully reflects light of the discharge lamps La. The illumination fixture 6 as described above can be realized by a well known technique, and therefore detailed description thereof is omitted.

[Description of Reference Numerals]

[0062]

1: Switching part
2: Resonant part
3: Drive part
4: Control part
5: Lighting detection part
6: Illumination fixture
61: Fixture main body
E: DC power source
La: Discharge lamp
Q1, Q2: Switching element
T: Balancer

Claims

1. A discharge lamp lighting device that lights a plurality of discharge lamps, the discharge lamp lighting device comprising:

a balancer having a plurality of windings each having one terminal connected to one terminal of a corresponding one of the discharge lamps;
a resonant part that is connected between both terminals of a series circuit of each of the windings of the balancer and a corresponding one of the discharge lamps, and constitutes a resonant circuit along with the series circuit;
a switching part that lies between a DC power source and the resonant part, includes at least one switching element, and according to on/off of the switching element, switches connection between the DC power source and the resonant part;
a drive part that on/off drives the respective switching elements of the switching part to supply AC power to the respective discharge lamps from the resonant part through the windings of the balancer;
a control part that controls a frequency of operation of the drive part to thereby control a frequency of the AC power outputted to the respective discharge lamps; and
a lighting detection part that detects start of a semi-lighting state where only a part of the plurality of discharge lamps is lit, wherein
when the lighting detection part detects the start of the semi-lighting state, the control part increases the frequency of the operation of the drive part, and an amount of the increase of the frequency is set to be large enough to make an effective value of an output voltage of the resonant part lower than an effective value for a case where the frequency is not changed.

2. The discharge lamp lighting device according to claim 1, comprising
a capacitor having both terminals that are respectively connected to a connecting point between one of the windings of the balancer and a corresponding one of the discharge lamps and a connecting point between the other winding and the other discharge lamp La.

3. The discharge lamp lighting device according to claim 1 or 2, comprising
an extinction detection part that detects a start of an extinction state where all of the discharge lamps are extinguished, wherein
after a predetermined delay time has passed since the extinction detection part detected the start of the extinction state, the control part decreases the frequency of the operation of the drive part to a frequency before the lighting detection part detects the start of the semi-lighting state.

4. The discharge lamp lighting device according to claim 1 or 2, wherein
the balancer has a detecting winding, and
when a detection voltage obtained by rectification and smoothing of an inter-terminal voltage of the detecting winding exceeds a predetermined lighting determination voltage, the lighting detection part detects the start of the semi-lighting state.

5. The discharge lamp lighting device according to claim 4, wherein
when the detection voltage falls below a predetermined extinction determination voltage, the control part decreases the frequency of the operation of the drive part, and
the extinction determination voltage is set to be lower than the lighting determination voltage.

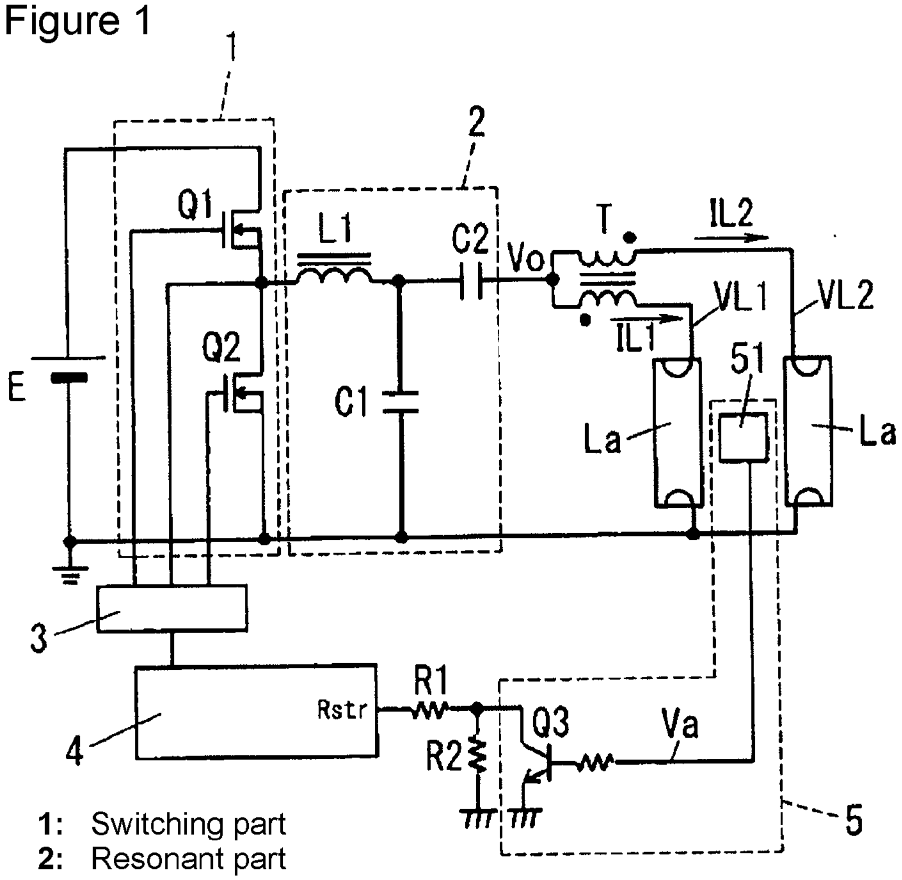
6. The discharge lamp lighting device according to claim 4, wherein
as a difference between the detection voltage and the lighting determination voltage increases, the control part more increases the frequency of the operation of the drive part.

7. The discharge lamp lighting device according to claim 1 or 2, wherein
when an effective value of an input current from a side of the discharge lamps to the resonant part exceeds a predetermined lighting determination current, the lighting detection part detects the start of the semi-lighting state.

8. An illumination fixture comprising:

the discharge lamp lighting device according to any one of claims 1 to 7; and a fixture main body that holds the discharge lamp lighting device.

Figure 1



1: Switching part
2: Resonant part
3: Drive part
4: Control part
5: Lighting detection part
E: DC power source
La: Discharge lamp
T: Balancer

Figure 2

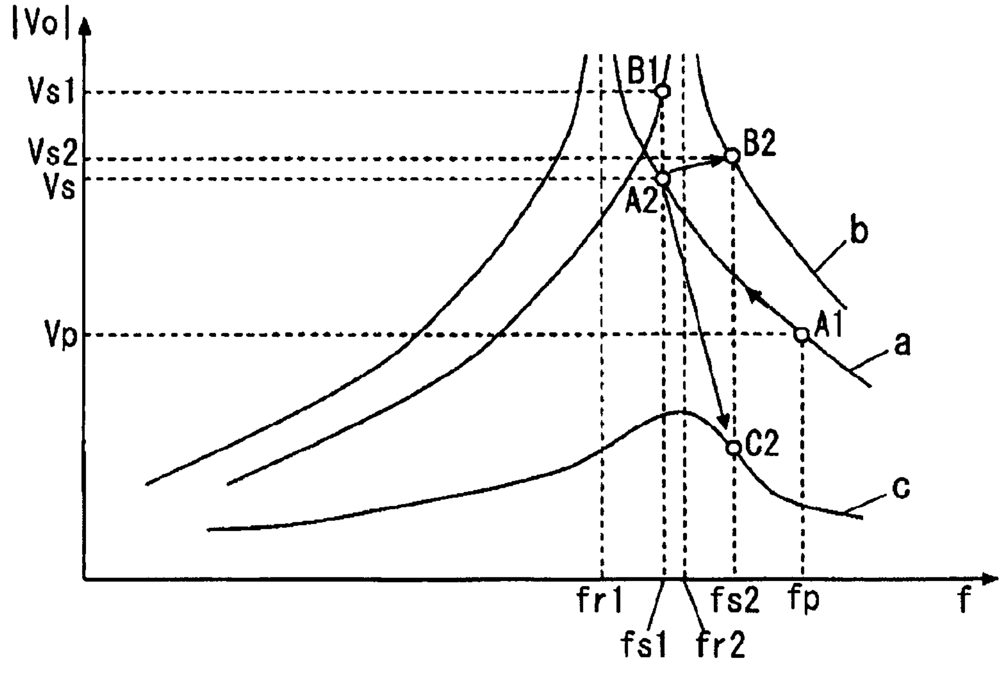


Figure 3

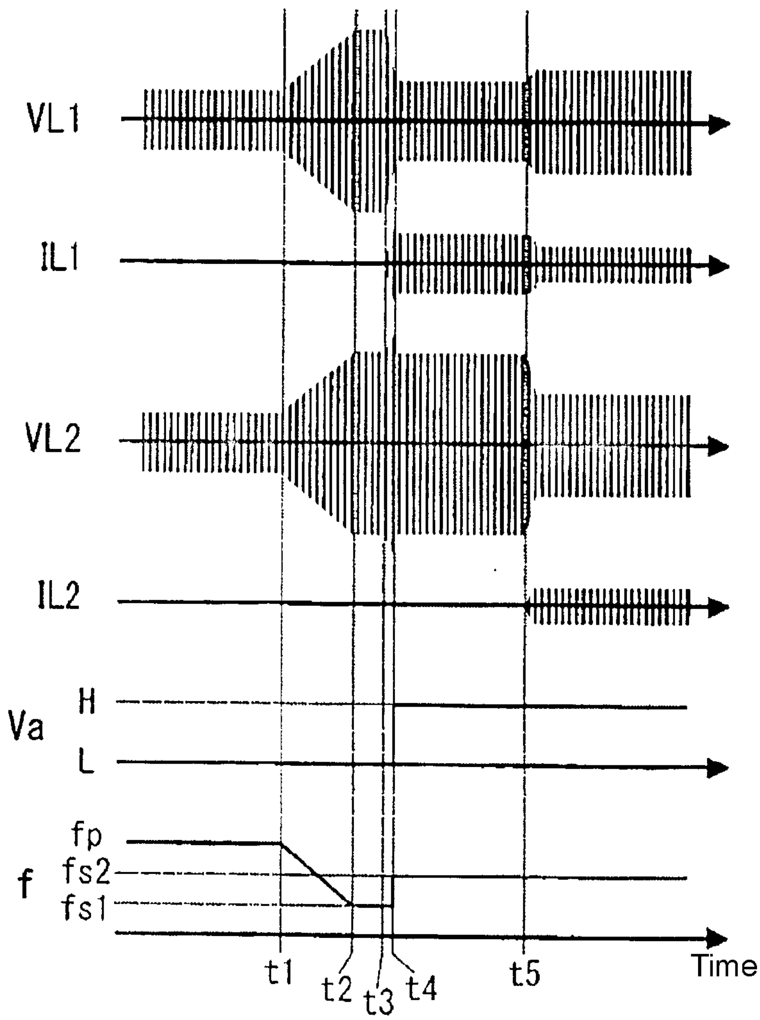


Figure 4

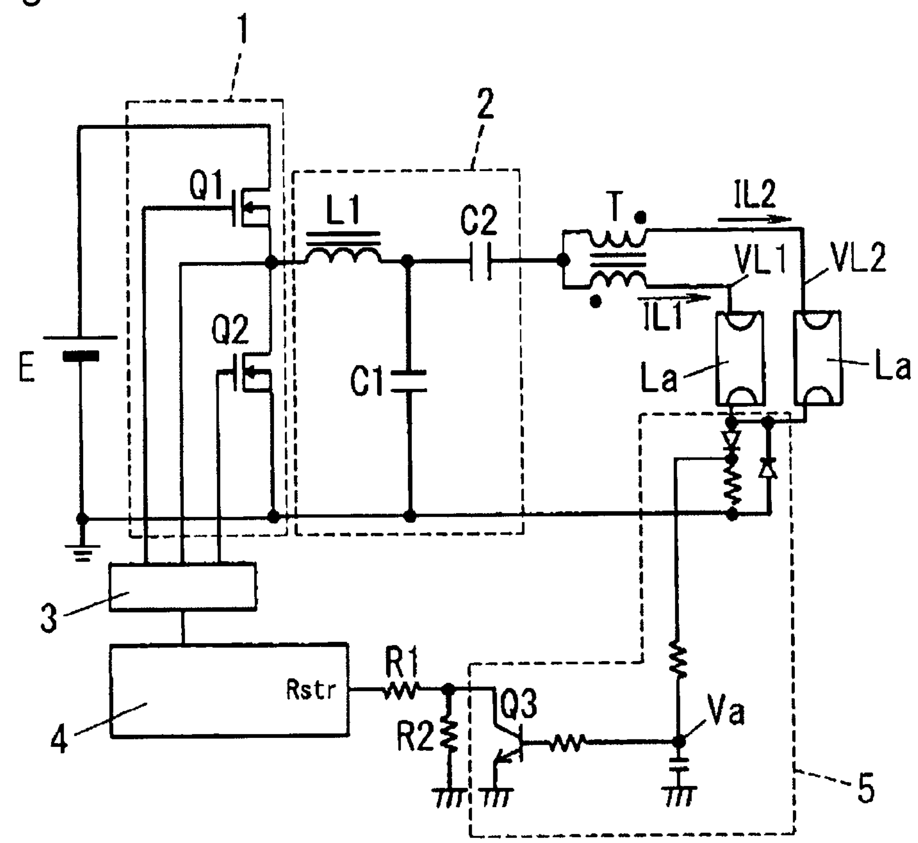


Figure 5

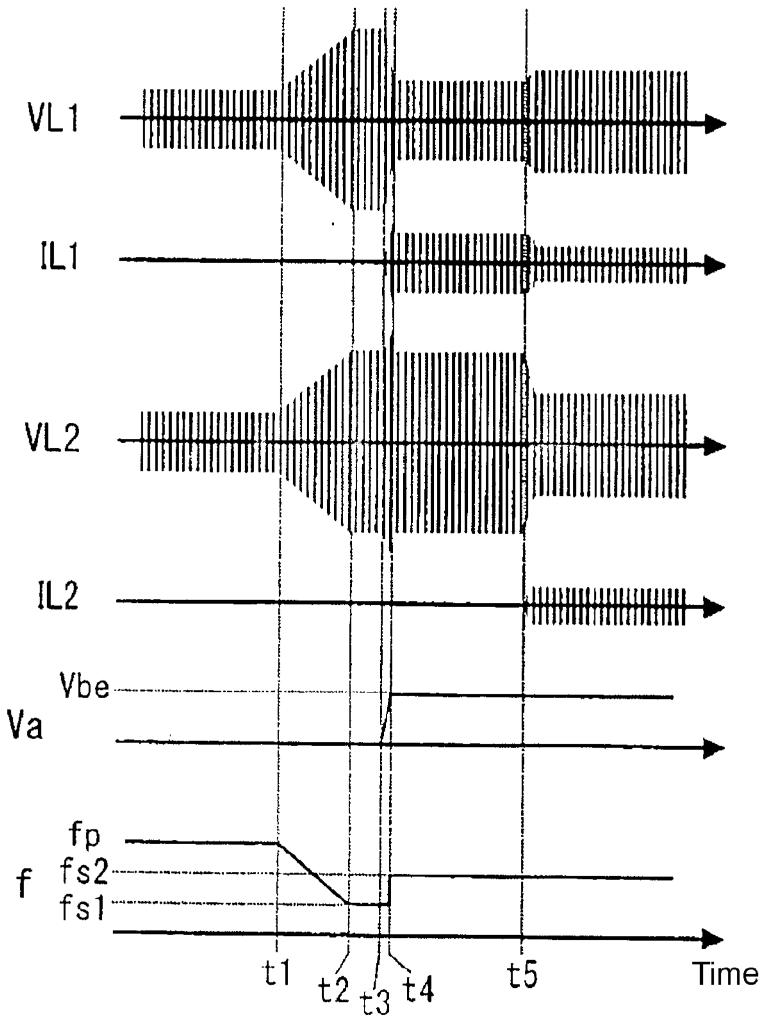


Figure 6

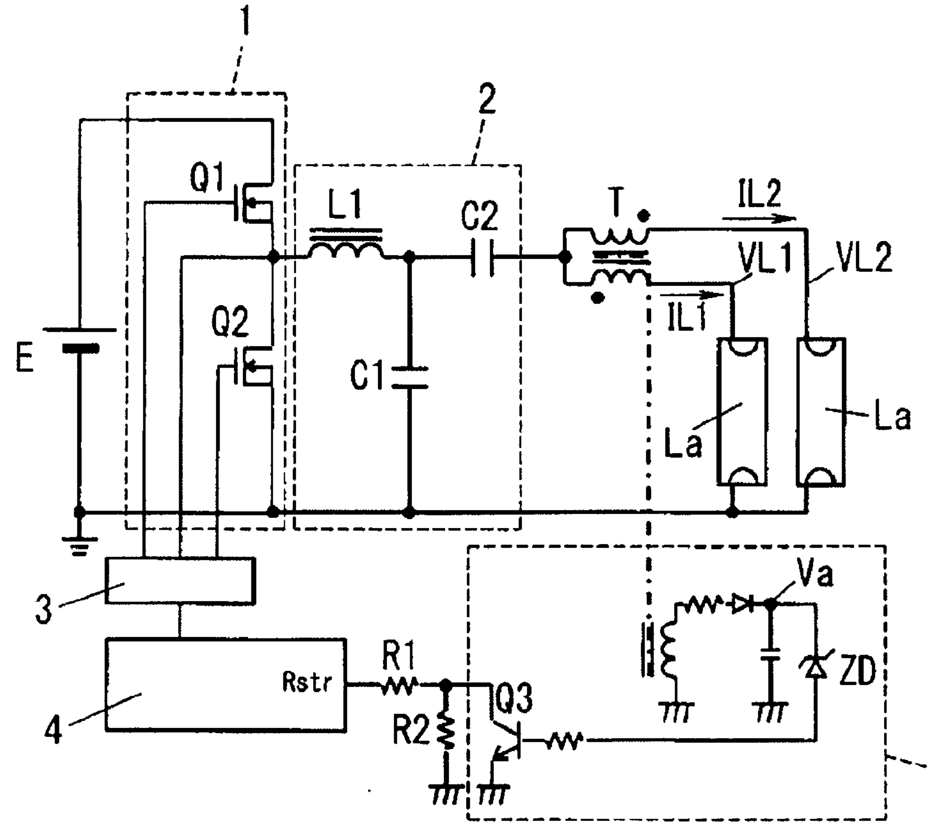


Figure 7

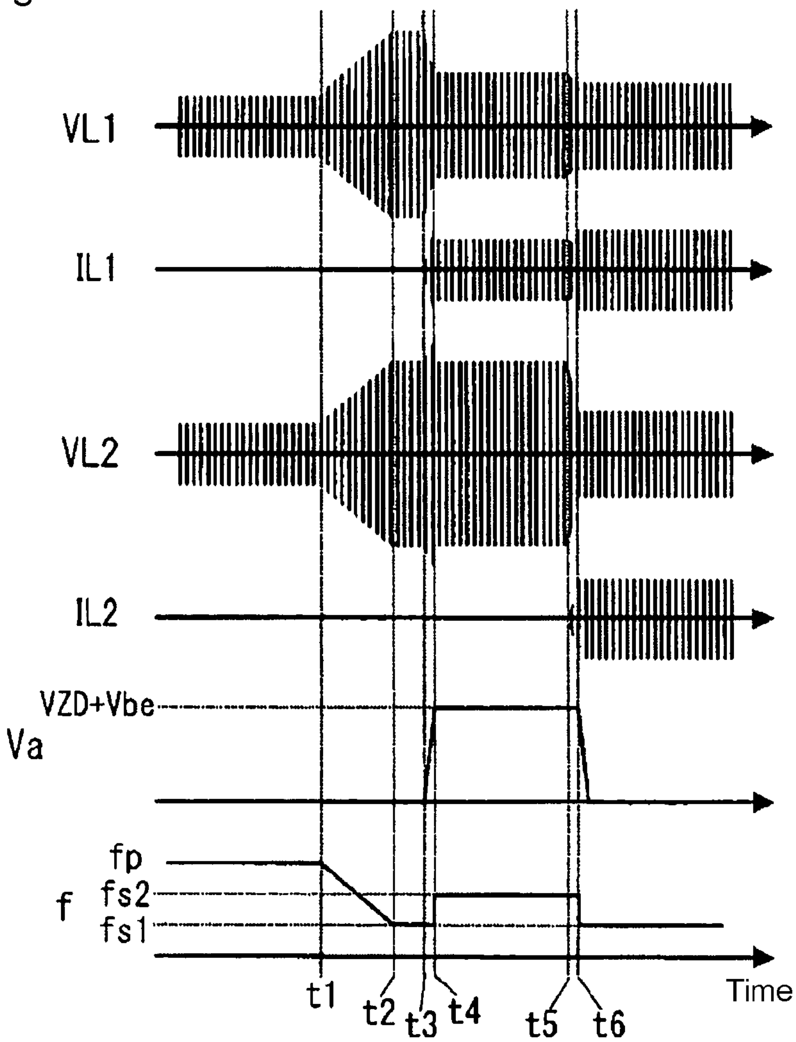


Figure 8

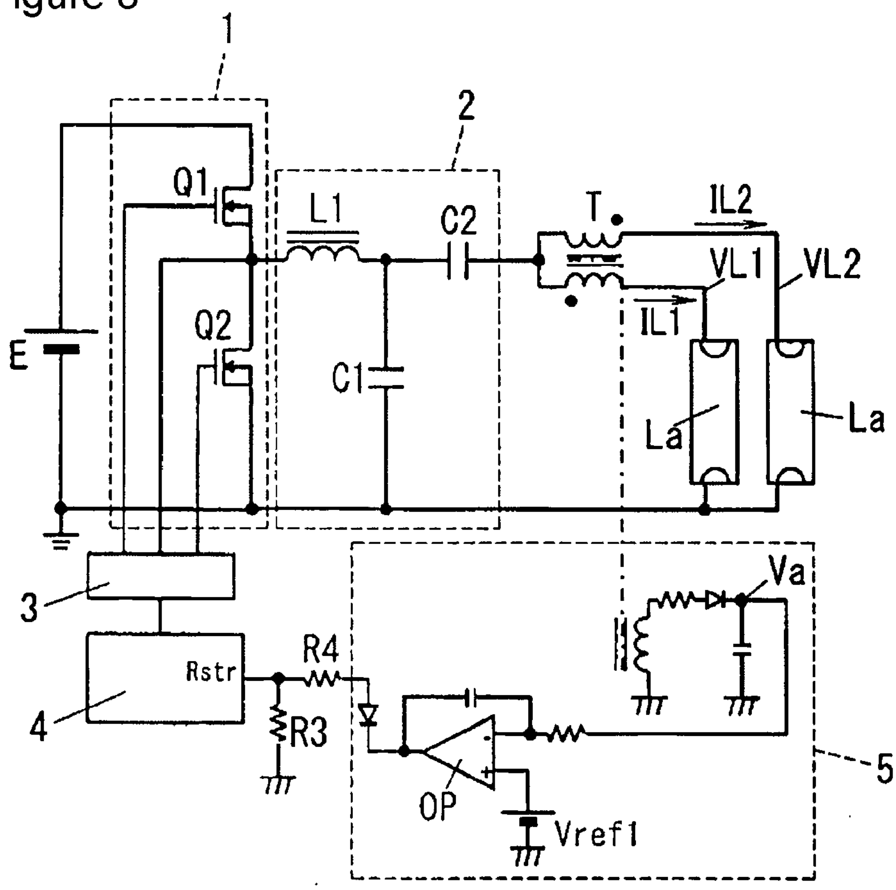

1
2
Q1
L1
C2
T
IL2
VL1
VL2
IL1
E
Q2
C1
La
La
3
Va
4
Rstr
R4
R3
OP
Vref1
5

Figure 9

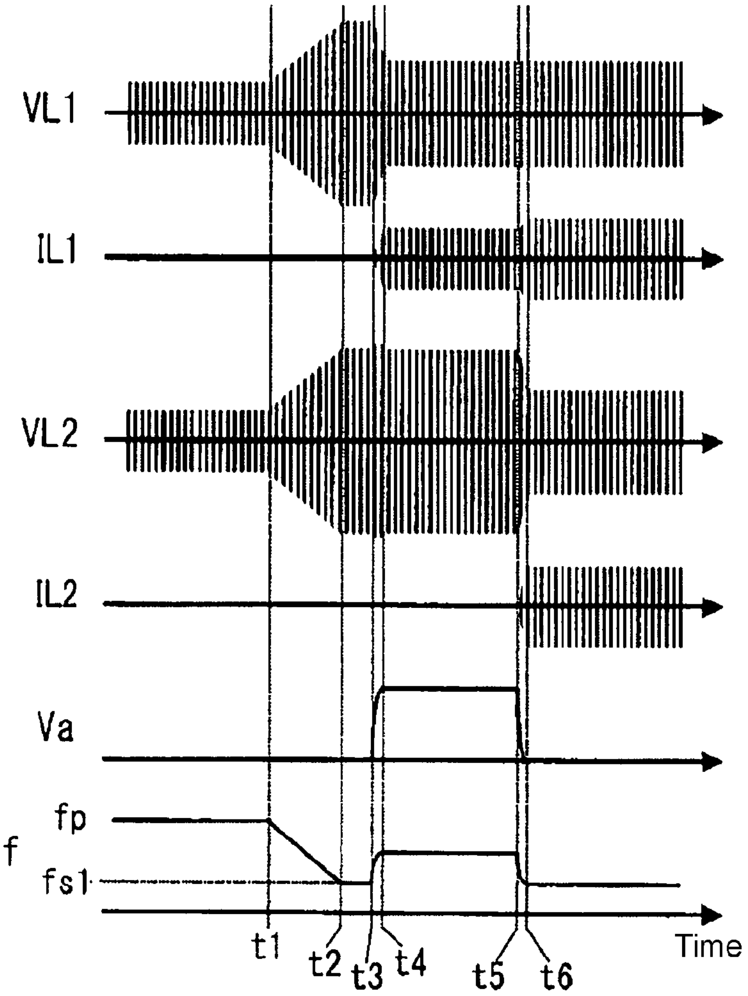
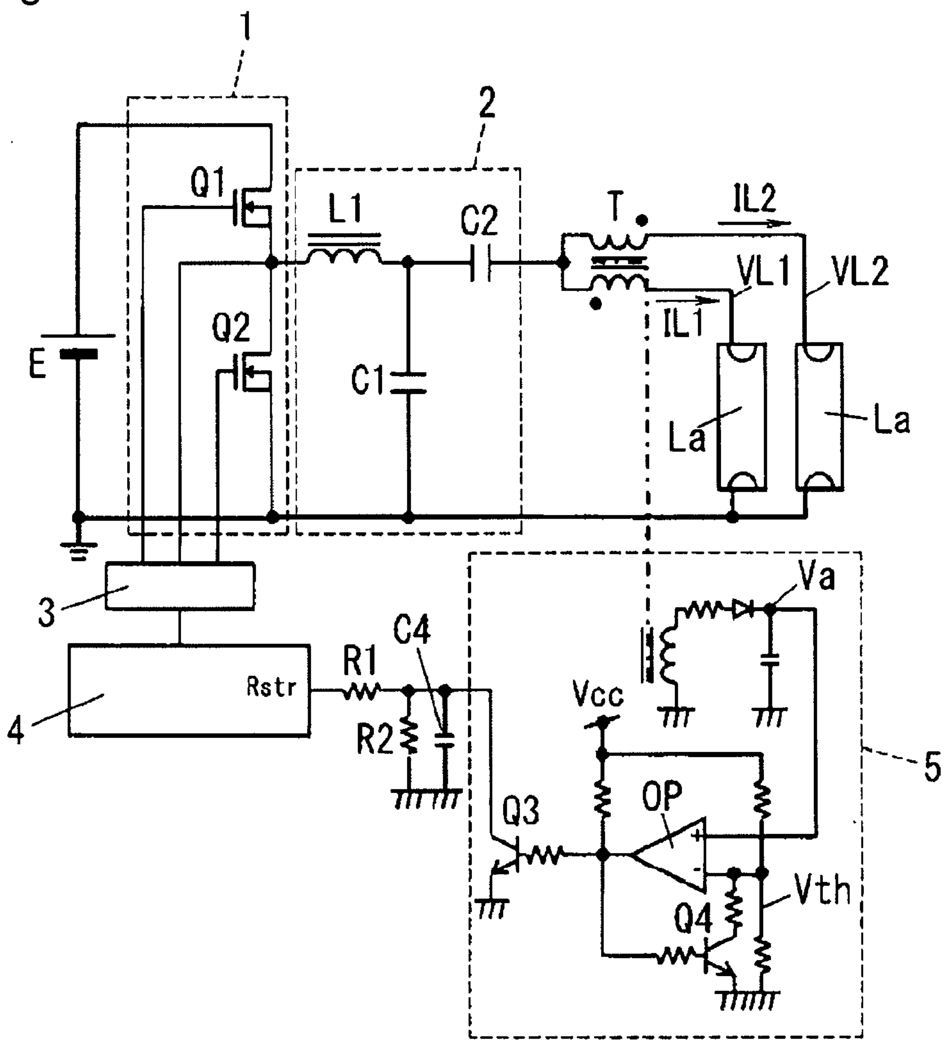


Figure 10


1
2
Q1
L1
C2
T
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VL1
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IL1
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C1
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La
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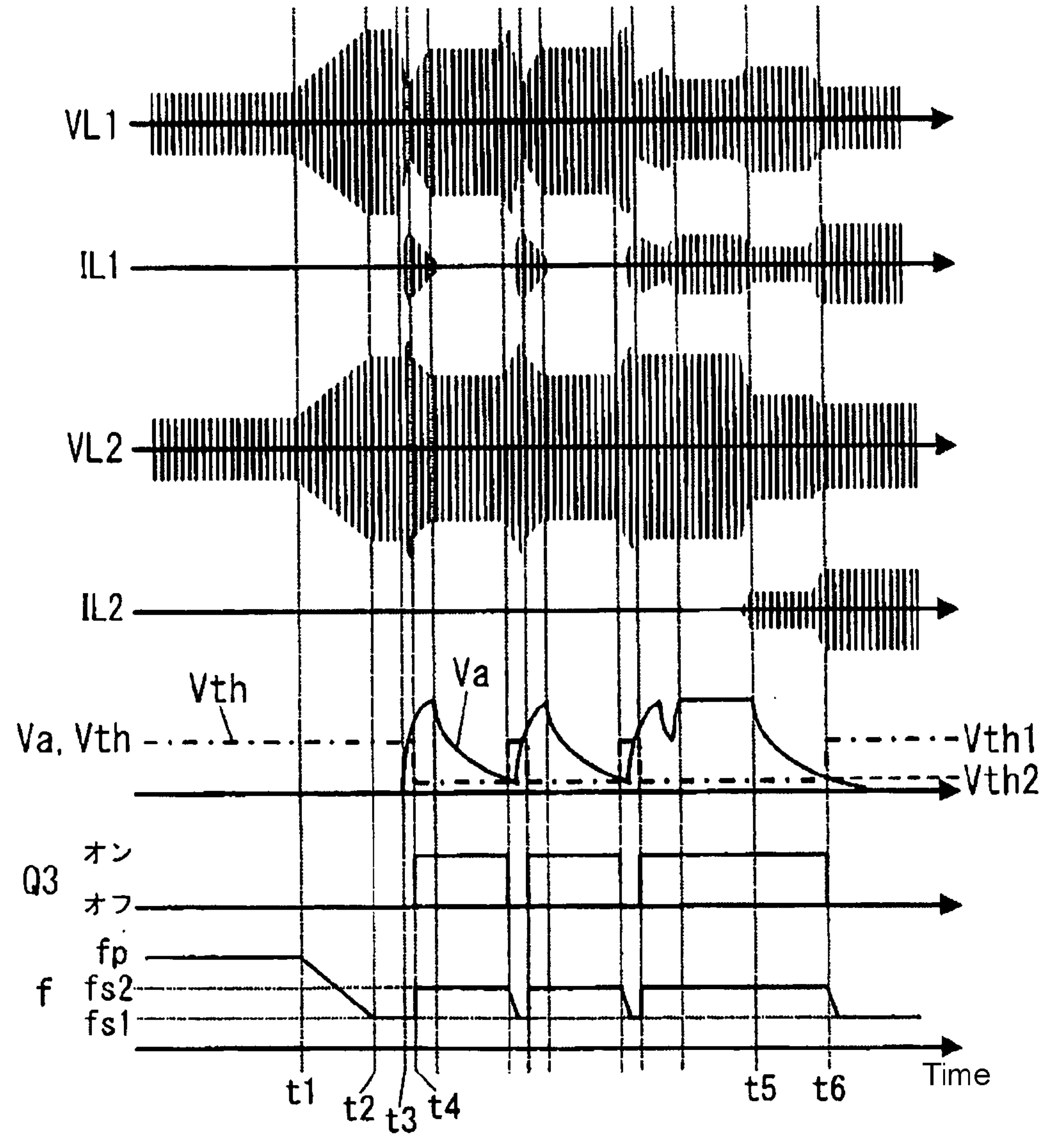
C4
R1
4
Rstr
R2
Vcc
5
OP
Q3
Vth
Q4

Figure 11


VL1
IL1
VL2
IL2
Vth
Va
Va, Vth
Vth1
Vth2
Q3
オン
オフ
f
fp
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t1
t2
t3
t4
t5
t6
Time

Figure 12

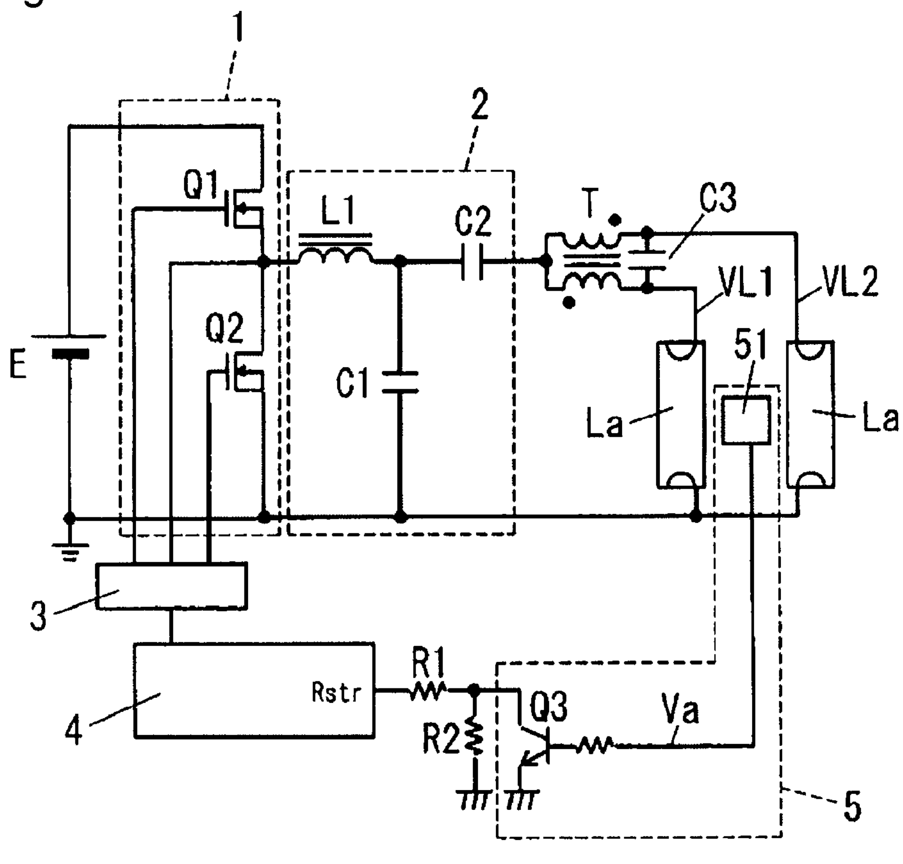


Figure 13

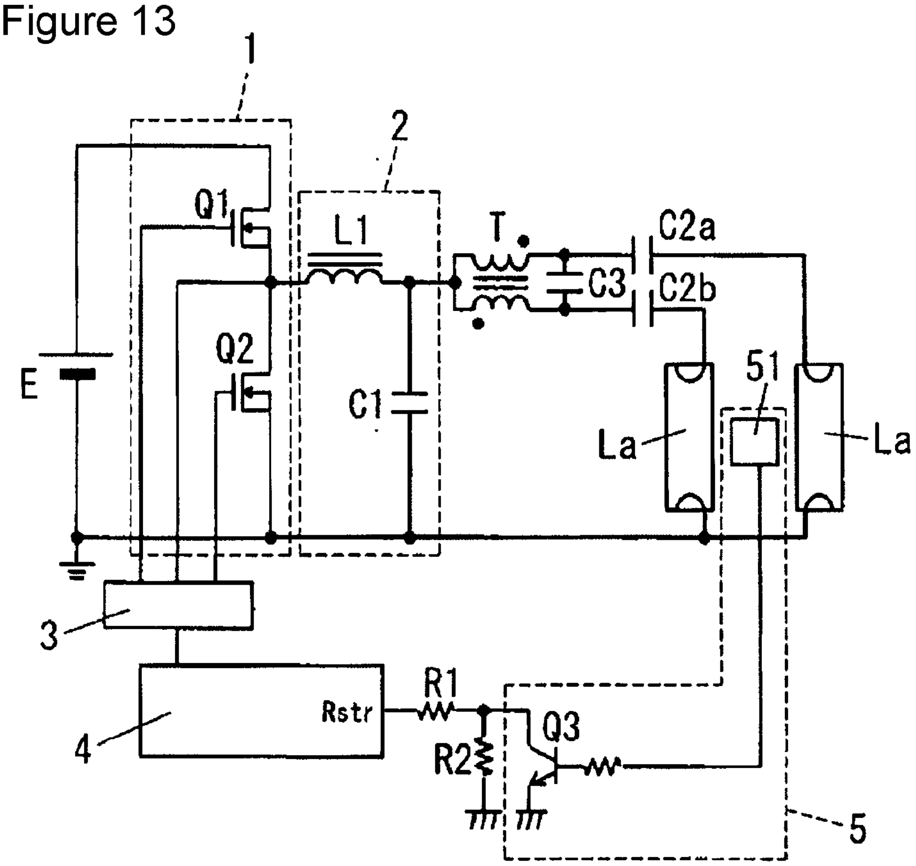


Figure 14

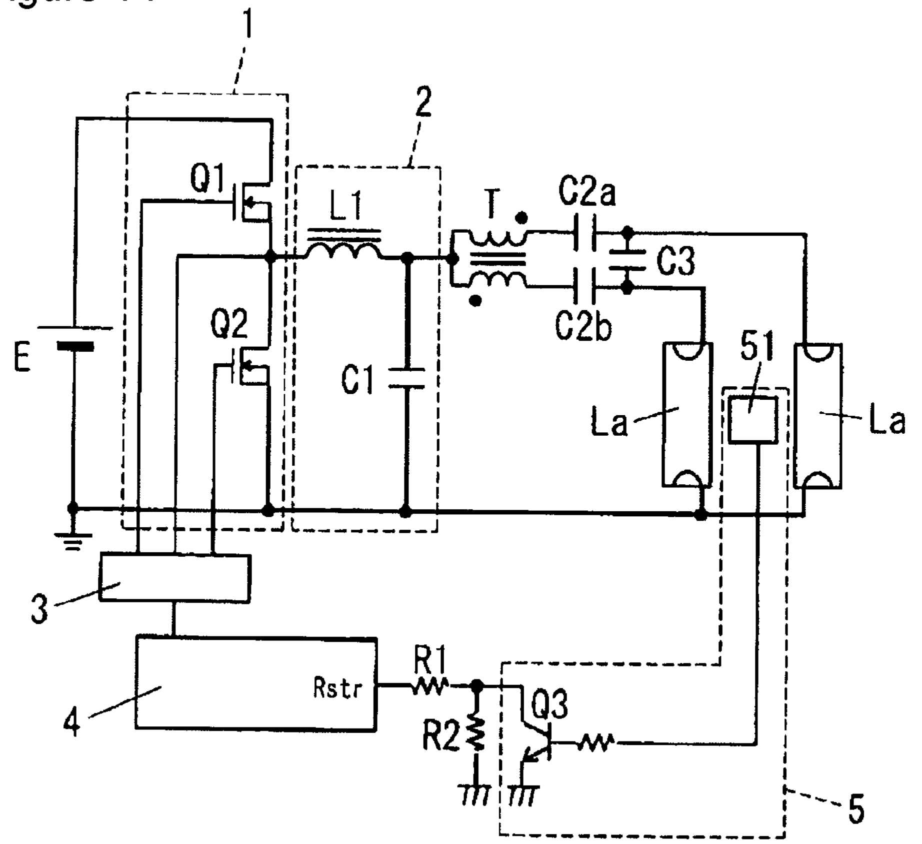


Figure 15

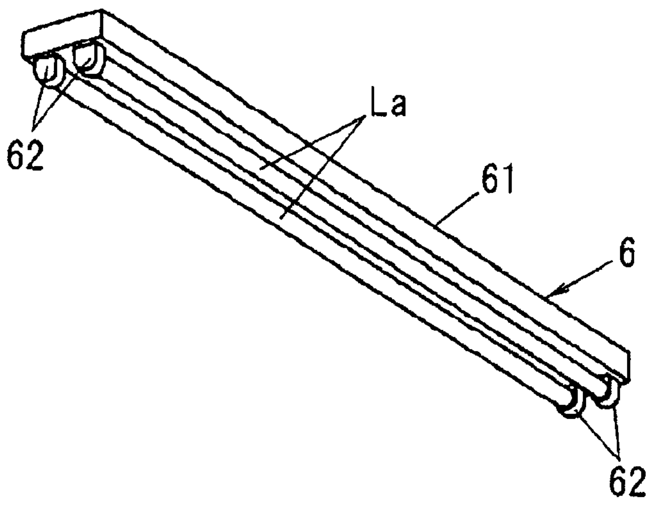


Figure 16

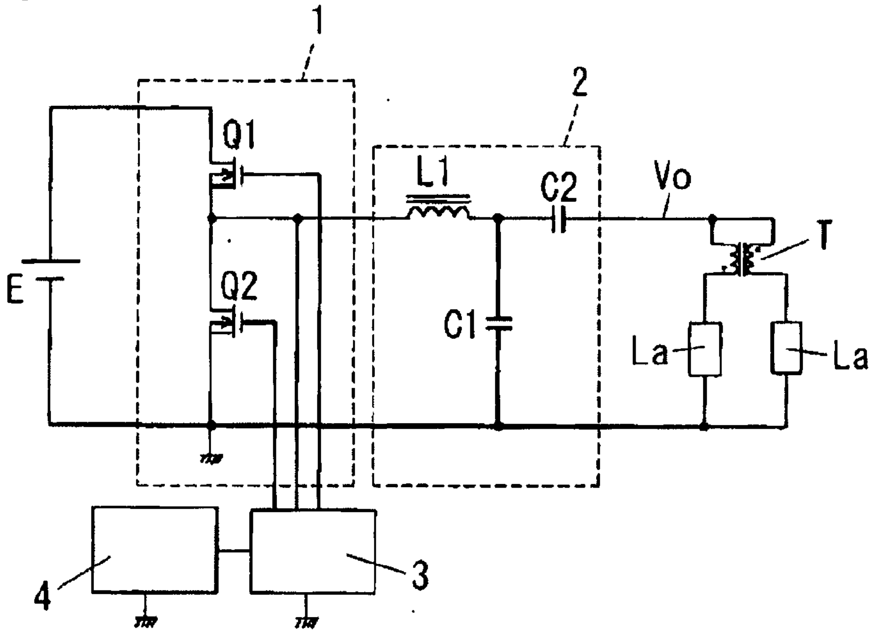
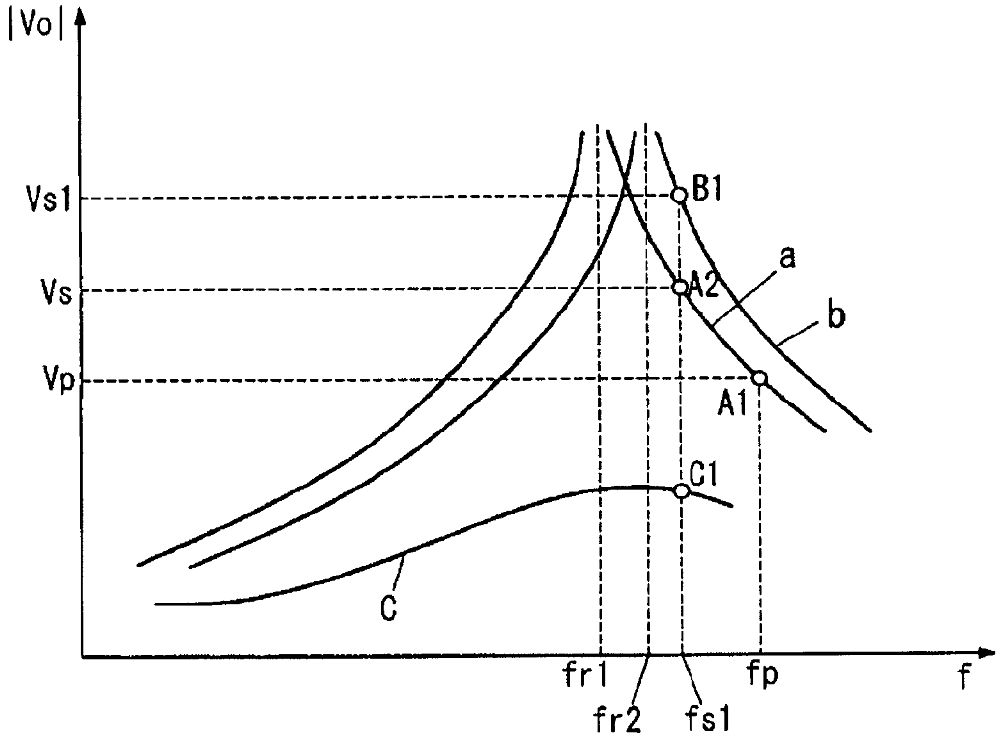


Figure 17



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Patent documents cited in the description

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