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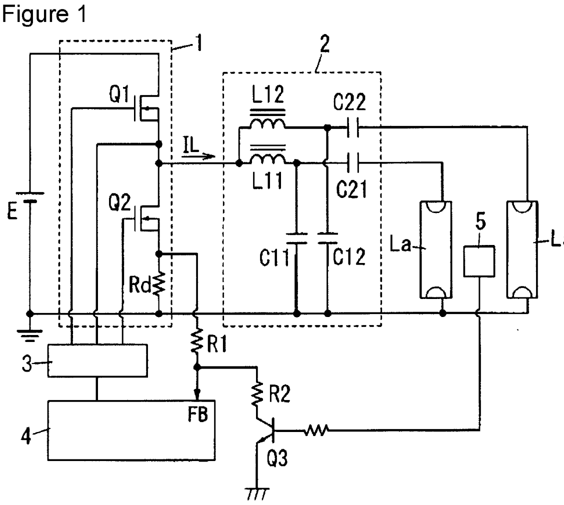
(54) Discharge lamp lighting device and illumination fixture using the same

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

[Means for Settlement] A plurality of discharge lamps La are lit by 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. 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 a semi-lighting state where a part of the plurality of discharge lamps La is lit. When the lighting detection part 5 detects the start of the semi-lighting state, the control part 4 controls the drive part 3 so as to sufficiently increase a frequency of the AC power supplied to each of the discharge lamps La to decrease an inter-terminal voltage of each of the discharge lamps La, and thereby electric stress placed on each of the 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
Q1, Q2: Switching element

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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 due to operation of the switching part, and lights the discharge lamp with the AC power.

[0003] Further, there is provided a discharge lamp lighting device configured such that the above discharge lamp lighting device is provided with: an electric quantity detection part that detects an electric quantity correlated to power outputted from the resonant part to the discharge lamp; and a control part that performs feedback control of a frequency of operation of a drive part so as to bringing the electric quantity detected by the electric quantity detection part close to a predetermined target value (e.g., see Patent literature 1).

[0004] As this sort of discharge lamp lighting device, there is proposed one that, for example, as illustrated in Fig. 17, uses one switching part 1 to light a plurality of (in the diagram, two) discharge lamps La.

[0005] In the following, the discharge lamp lighting device in Fig. 17 is described in detail.

[0006] Each of the discharge lamps La is a hot cathode type discharge lamp, and has filaments as a pair of electrodes.

[0007] The switching part 1 includes a series circuit of two switching elements Q1 and Q2 connected between output terminals of a DC power source E. Each of the switching elements Q1 and Q2 includes, for example, an n-channel MOSFET. Also, a lower voltage side output terminal of the DC power source E is connected to the ground.

[0008] The resonant part 2 includes two sets of LC resonant circuits each provided for each of the discharge lamps La, and each of the LC resonant circuits includes: an inductor L11 or L12 having one terminal connected to a connecting point between the switching elements Q1 and Q2; a capacitor (hereinafter referred to as a "parallel capacitor") C11 or C12 connected between the other terminal of the inductor L11 or L12 and the ground; and a capacitor (hereinafter referred to as a "series capacitor") C21 or C22 having one terminal connected to the other terminal of the inductor L11 or L12 and the other terminal connected to one terminal (i.e., one of the filaments) of a corresponding one of the discharge lamp La. The other terminal (a filament on a side not connected to the series capacitor C21 or C22) of each of the discharge lamps La is connected to the ground.

[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 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] A drive part 3 that on/off drives the respective switching elements Q1 and Q2 of the switching part 1, and a control part 4 that controls the drive part 3 are respectively realized with well known electronic circuits, and therefore detailed illustration and description thereof are omitted.

[0011] Further, between the switching element Q1 on a low voltage side (low side) of the switching part 1 and the ground, a current detecting resistor Rd is connected. The control part 4 has a feedback terminal FB inputted with an inter-terminal voltage (hereinafter referred to as a "detection voltage") of the current detecting resistor Rd, and performs feedback control of a frequency of operation of the drive part 3 (i.e., a frequency of a voltage outputted to each of the discharge lamps La, and hereinafter referred to as an "operating frequency") f so as to match an effective value of the input voltage to the feedback terminal FB with a predetermined reference voltage. Note that the above detection voltage, i.e., the inter-terminal voltage of the current detecting resistor Rd is proportional to a sum of currents flowing through the respective discharge lamps La (hereinafter referred to as a "resonant current") IL. That is, the above feedback control makes an effective value |IL| of the resonant current IL as an electric quantity equal to a target value obtained by multiplying a ratio of the effective value |IL| of the resonant current IL to the input voltage to the feedback terminal FB by the above reference voltage.

[Conventional Technique Literature]

[Patent Literature]

[0012]

[Patent literature 1] JPA 2010-67562

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0013] Fig. 18 illustrates relationship between an effective value |VL| of an inter-terminal voltage of the discharge lamps La (hereinafter referred to as a "lamp voltage") and an operating frequency f, in which a state where the discharge lamps La are extinguished is indicated by a curve a, and a state where the discharge lamps La are lit is indicated by a curve b. Also, Fig. 19 illustrates relationship between the resonant current IL and the operating frequency f, in which a state where both of the discharge lamps are extinguished is indicated by a curve a; a state where both of the discharge lamps La are lit is indicated by a curve b; and a state where one of the discharge lamps La is lit and the other discharge lamp La is extinguished is indicated by a curve c.

[0014] To start lighting the respective discharge lamps La, a preheating operation is first performed, in which in a state where the operating frequency f is changed to a predetermined initial frequency fp high enough with respect to a resonant frequency fr of the resonant part 2 such that the effective value |VL| of the lamp voltage becomes equal to a low value Vp to the extent of not starting discharge in each of the discharge lamps La, the respective filaments of each of the discharge lamps La are sufficiently preheated. The discharge lamp lighting device is provided with a preheating circuit (not illustrated) that applies a current to the respective filaments during the above heating operation. The preheating circuit as described above can be realized by a well known technique, and therefore illustration and description thereof are omitted.

[0015] Then, the control part 4 starts the above feedback control. On the basis of this, operation (hereinafter referred to as a "starting sweep operation") that gradually brings the effective value |IL| of the resonant current IL close to a predetermined target value (hereinafter referred to as a "target current") Is1 is performed. In the process of the starting sweep operation, an operating points changes from A1 to A2, and the operating frequency f gradually decreases from the initial frequency fp to a predetermined starting frequency fs. The above target current Is1 is set to a value that allows the effective value |VL| of the lamp voltage to become equal to a value Vs high enough to the extent of being able to start the discharge of each of the discharge lamps La. From the above, each of the discharge lamps La starts lighting (i.e., starts).

[0016] Also, there is provided lighting completion detecting means (not illustrated) adapted to detect the state where all of the discharge lamps La are lit (hereinafter referred to as a "lighting completion state"), and after the lighting completion detecting means has detected the lighting completion state, the control part 4 controls the drive part 3 to make an optical output of each of the discharge lamps La equal to an optical output according to an externally inputted lighting control signal. Further, if even after a predetermined time has passed since the completion of the preheating operation, the lighting completion state is not detected, the control part 4 may stop the operation of the drive part 3 to respectively keep the switching elements Q1 and Q2 of 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.

[0017] However, in the process of the start as described above, if a lighting situation transitions to a state where a lighted discharge lamp La and an unlighted discharge lamp La are mixed (hereinafter referred to as a "semi-lighting state"), a characteristic becomes one as indicated by a curve c in Fig. 19. Accordingly, on the basis of the feedback operation that attempts to match the effective value |L1| of the resonant current IL with the target current Is1, the operating points changes from a point C1 to a point C2 illustrated in Fig. 19. As a result, excessively high voltages are respectively outputted to the discharge lamps, for example, in the case of the unlighted discharge lamp La, the operating point changes to a point A3 illustrated in Fig. 18, and in the case of the lighted discharge lamp La, the operating point changes to a point B2 illustrated in Fig. 18

[0018] The present invention is made for the above reason, and an object thereof is to provide a discharge lamp lighting device capable of reducing stress that is placed on respective discharge lamps at the start time, and an illumination fixture using the discharge lamp lighting device.

[Means adapted to solve the Problems]

[0019] 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 resonant part that is connected to each of the discharge lamps and constitutes a resonant circuit along with each of the discharge lamps; 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 thereby supply AC power to the respective discharge lamps from the resonant part; an electric quantity detection part that detects one electric quantity correlated to an inter-terminal voltage of each of the discharge lamps; a control part that performs feedback control of a frequency of operation of the drive part so as to bring the electric quantity detected by the electric quantity detection part close to a predetermined target value; 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 changes the target value so as to decrease an effective value of the inter-terminal voltage of each of the discharge lamps.

[0020] Preferably, in the discharge lamp lighting device, the resonant part includes one LC resonant circuit; and a balancer having a plurality of windings each having one terminal connected to one terminal of a corresponding one of the discharge lamps and the other terminal connected to the resonant part is provided, the plurality of windings being mutually magnetically coupled.

[0021] 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.

[0022] Further, preferably, in the discharge lamp lighting device, the electric quantity detection part detects, as the electric quantity, currents flowing through the switching elements of the switching part.

[0023] Also, preferably, in the discharge lamp lighting device, the electric quantity detection part detects, as the electric quantity, an inter-terminal voltage of any component of the resonant part.

[0024] Further, preferably, in the discharge lamp lighting device, the lighting detection part compares an effective value of an input current from a side of the discharge lamps to the resonant part with a predetermined switching threshold value, and when the effective value of the input current exceeds the switching threshold value, detects the start of the semi-lighting state.

[0025] Also, preferably, in the discharge lamp lighting device, the balancer has a detecting winding; and when a detection voltage obtained by rectifying and smoothing 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.

[0026] Further, preferably, in the discharge lamp lighting device, the balancer has a detecting winding; the lighting detection part generates a detection voltage by rectifying and smoothing an inter-terminal voltage of the detecting winding; and the control part decreases the target value as the detection voltage increases.

[0027] Also, 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 the semi-lighting state.

[0028] Also, an illumination fixture of the present invention is provided with: any of the above the discharge lamp lighting devices; and a fixture main body that holds the discharge lamp lighting device.

[Effect of the Invention]

[0029] According to the present invention, when a lighting detection part detects start of a semi-lighting state, a target value is changed so as to decrease an inter-terminal voltage of each of discharge lamps, so that electric stress placed on each of the discharge lamps at the start time is reduced.

[Brief Description of the Drawings]

[0030]

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

[Fig. 2] Fig. 2 is an explanatory diagram illustrating relationship between an operating frequency f and the effective value |IL| of a resonant current in the embodiment.

[Fig. 3] Fig. 3 is a circuit block diagram illustrating a variation of the embodiment.

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

[Fig. 5] Fig. 5 is a circuit block diagram illustrating still another variation of the embodiment.

[Fig. 6] Fig. 6 is an explanatory diagram illustrating relationship between the operating frequency f and the effective value |VL| of a lamp voltage in the variation of Fig. 4.

[Fig. 7] Fig. 7 is an explanatory diagram illustrating relationship between the operating frequency f and the effective value |IL| of the resonant current in the variation of Fig 4.

[Fig. 8] Fig. 8 is a circuit block diagram illustrating yet another variation of the embodiment.

[Fig. 9] Fig. 9 is a circuit block diagram illustrating still yet another variation of the embodiment.

[Fig. 10] Fig. 10 is a circuit block diagram illustrating further variation of the embodiment.

[Fig. 11] Fig. 11 is a circuit block diagram illustrating still further variation of the embodiment.

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

[Fig. 13] Fig. 13 is an explanatory diagram illustrating time variations of a lamp voltage VL1 of one of discharge lamps La, a lamp current IL1 flowing through the one discharge lamp La, a lamp voltage VL2 of the other discharge lamp La, a detection voltage Va, a gate-source voltage Vgs of a control switching element Q3, and the operating frequency f for the case where as the control switching element Q3 in the variation of Fig. 10, a MOSFET is used.

[Fig. 14] Fig. 14 is an explanatory diagram illustrating time variations of a lamp voltage VL1 of one of discharge lamps La, the lamp current IL1 flowing through the one discharge lamp La, the lamp voltage VL2 of the other discharge lamp La, the detection voltage Va, the gate-source voltage Vgs of the control switching element Q3, and the operating frequency f in the variation of Fig. 12.

[Fig. 15] Fig. 15 is a circuit block diagram illustrating still yet further variation of the embodiment.

[Fig. 16] Fig. 16 is a perspective view illustrating an example of an illumination fixture using the embodiment

[Fig. 17] Fig. 17 is a circuit block diagram illustrating a conventional example.

[Fig. 18] Fig. 18 is an explanatory diagram illustrating relationship between the operating frequency f and the effective value |VL| of a lamp voltage in the conventional example.

[Fig. 19] Fig. 19 is an explanatory diagram illustrating relationship between the operating frequency f and the effective value |IL| of a resonant current in the conventional example.

[Best Mode for Carrying Out the Invention]

[0031] A best mode for carrying out the present invention will hereinafter be described referring to the drawings.

[0032] A basic configuration of the present embodiment is in common with the conventional example described with Fig. 17, and therefore description of common parts is omitted.

[0033] In the present embodiment, as illustrated in Fig. 1, the feedback terminal FB of the control part 4 is connected to the current detecting resistor Rd through a resistor R1, and also to the ground through a series circuit of another resistor R2 and a switching element (hereinafter referred to as a "control switching element") Q3 including an npn type transistor.

[0034] Also, the present embodiment is provided with a lighting detection part 5 that: detects the start of the semi-lighting state; at least during a period before the semi-lighting state is detected at the start time, keeps the control switching element Q3 in an on state; and when the start of the semi-lighting state is detected, off controls the control switching element Q3. That is, at the start time, until the lighting detection part 5 detects the start of the semi-lighting state, the input voltage to the feedback terminal FB is kept in a lowered state caused by voltage division by the resistors Ra and R2, and when the lighting detection part 5 detects the start of the semi-lighting state, the control switch Q3 is turned off to thereby increase the input voltage to the feedback terminal FB. Note that even in the case where the above series circuit of the control switching element Q3 and the resistor R2 is connected in parallel to the current detecting resistor Rd, the same effect is obtained.

[0035] Note that, in the feedback control performed by the control part 4, the target value of the effective value |IL| of the resonant current IL is a value obtained by multiplying a ratio of the effective value |IL| of the resonant current IL to the input voltage to the feedback terminal FB by the predetermined reference voltage, and therefore the increase in input voltage to the feedback terminal FB as described above means that, in other words, the above target value is decreased.

[0036] According to the above configuration, when the start of the semi-lighting state is detected, the target value (target current) for the feedback control is decreased in control part 4, and thereby the effective value |VL| of the lamp voltage VL is decreased in each of the discharge lamps La, so that electric stress placed on each of the discharge lamps La at the start time is reduced.

[0037] For example, in the semi-lighting state having a characteristic as indicated by a curve b in Fig. 2, the effective value |IL| of the resonant current IL that is achieved when the operating frequency f is changed to the operating frequency (starting frequency) fs that achieves a target current (hereinafter referred to as a "first target current") Is1 before the decrease in a characteristic curve a in the extinction state is defined as a second target current Is2, and if a target current that is the above-described decreased target value is matched with the second target current Is2, even after the start of the semi-lighting state, the operating frequency f is kept at the starting frequency fs as indicated by operating points C1 and B1 in Fig. 2, and therefore the inter-terminal voltage of the unlighted discharge lamp La is also kept.

[0038] Note that as a method for decreasing the target value for the feedback control in the control part 4, instead of decreasing the input voltage to the feedback terminal FB as described above, as illustrated in Fig. 3, a terminal (hereinafter referred to as a "setting terminal") VR that receives a change in reference voltage to be compared with the input voltage to the feedback terminal FB may be provided in the control part 4, and the setting terminal VR may be connected with the lighting detection part 5. Specifically, for example, during a period during which an input voltage to the setting terminal VR is equal to or more than a predetermined threshold voltage (e.g., a voltage equivalent to the above on voltage Vbe), the control part 4 makes the reference voltage lower than that during a period during which the input voltage to the setting terminal VR is less than the threshold voltage. Such a control part 4 can be realized by a well known technique, and therefore detailed illustration and description thereof are omitted. However, rather, the configuration where, as illustrated in Fig. 1, the input voltage to the feedback terminal FB is changed has an advantage of easily using an existing integrated circuit as the control part 4.

[0039] Also, instead of, in the resonant part 2, providing the LC resonant circuit for each of the discharge lamps La, as illustrated in Fig. 4 or 5, the resonant part 2 may include only one LC resonant circuit, and each of the discharge lamps La may be connected to the resonant part 2 through a corresponding one of windings of a balancer T. To describe in detail, the balancer T is a so-called balancer transformer having a plurality of windings that are, for example, wound on a common iron core to be mutually magnetically connected. Also, in each of examples of Figs. 4 and 5, the resonant part 2 is provided with a series circuit that is connected between the connecting point between the switching elements Q1 and Q2 and the ground and includes an inductor L1 and a parallel capacitor C1. Also, in the example of Fig. 4, the resonant part 2 is provided with a series capacitor C2 of which one terminal is connected to a connecting point between the inductor L1 and the parallel capacitor C1 and the other terminal is connected to one terminal of each of the windings of the balancer T as an output terminal of the resonant part 2, and the other terminal of each of the windings of the balancer T is connected to one of terminals (one of filaments) of a corresponding one of the discharge lamps La. In the example of Fig. 5, the series capacitor C2 is absent in the resonant part 2, but the connecting point between the inductor L1 and the parallel capacitor C1 serves as the output terminal of the resonant part 2, whereas the other terminal of each of the windings of the balancer T is connected to one of the terminals of a corresponding one of the discharge lamps La through a series capacitor C21 or C22. Further, in each of the examples of Figs. 4 and 5, the respective windings of the balancer T connect the one terminal (the other terminal in the above) on the discharge lamp La side to each other through a capacitor C3.

[0040] 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, in each of the examples of Figs. 4 and 5, a technique disclosed in JP 2008-218333A is employed to provide the 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. On the basis of this, despite the inductance of the balancer T, the difference in optical output between the discharge lamps La in the lighting state can be decreased.

[0041] Regarding the example of Fig. 4, relationship between the effective value |VL| of the lamp voltage VL and the operating frequency f is illustrated in Fig. 6, and relationship between the effective value |IL| of the resonant current IL and the operating frequency f is illustrated in Fig. 7. Also, in Fig. 6, a curve a1 represents the lamp voltage VL in each of the discharge lamps La in the extinction state; a curve b1 represents the lamp voltage VL in each of the discharge lamps La in the lighting completion state; a curve a2 represents the lamp voltage VL in the unlighted discharge lamp La in the semi-lighting state; and a curve b2 represents the lamp voltage VL in the lighted discharge lamp La in the semi-lighting state. If at the start time of the semi-lighting state, the target current remains at the first target current Is1 without change, the operating frequency f is changed to an operating frequency fs1 (operating points A3, C2) slightly higher than the starting frequency fs and thereby in each of the discharge lamps La, the lamp voltage VL is excessively increased; however, by decreasing the target current to the appropriate second target current Is2, the operating frequency f can be changed to a sufficiently high frequency fs2 to thereby decrease the lamp voltage VL in each of the discharge lamps La (operating points A4, B3, C2). After the decrease of the target current as described above, the operating point immediately after the start of the lighting completion state where both of the discharge lamps La are lit is on3 indicated by B4 in Fig. 6 or 7.

[0042] Further, the electric quantity used by the control part 4 for the feedback control is not limited to the resonant current IL, but may be an electric quantity correlated to the inter-terminal voltage of each of the discharge lamps La. For example, as the input voltage to the feedback terminal FB of the control part 4, in place of the inter-terminal voltage of the current detecting resistor Rd, as illustrated in Fig. 8, the inductor L1 of the resonant part 2 may be provided with a secondary winding to input an inter-terminal voltage of the secondary winding (i.e., a voltage proportional to an inter-terminal voltage of the inductor L1), or as illustrated in Fig. 9, an inter-terminal voltage of the parallel capacitor C1 (i.e., an output voltage of the resonant part 2) may be inputted. As the electric quantity used by the control part 4 for the feedback control, in the example of Fig. 8, the inter-terminal voltage of the inductor L1 as a component of the resonant part 2 is used, whereas in the example of Fig. 9, the inter-terminal voltage of the parallel capacitor C1 as a component of the resonant part 2 is used. In the example of Fig. 8, the inter-terminal voltage of the above secondary winding is, as with the inter-terminal voltage of the current detecting resistor Rd in the example of Fig. 1, inputted to the feedback terminal FB through the resistor R1. Also, in the example of Fig. 9, the inter-terminal voltage of the parallel capacitor C1 is, as with the inter-terminal voltage of the current detecting resistor Rd in the example of Fig. 1, inputted to the feedback terminal FB through the resistor R1, and also a resistor R3 connected in parallel to the series circuit of the resistor R2 and the control switching element Q3 is added. In any of the examples of Figs. 8 and 9, when the control switching element Q3 is turned off, a ratio of the input voltage to the feedback terminal FB to the above electric quantity is increased to thereby substantially decrease the target value for the feedback control.

[0043] Figs. 10 and 11 respectively illustrate specific examples of the lighting detection part 5.

[0044] First, to describe the example of Fig. 10, the lighting detection part 5 is provided with: a resistor R4 that lies between the base of the control switching element Q3 and a constant voltage Vcc; and an npn type transistor (hereinafter referred to as an "output transistor") Q4 that lies between the base of the control switching element Q3 and the ground. Also, the balancer T is provided with a detecting winding; the lighting detection part 5 has a circuit that generates a detection voltage Va by rectifying and smoothing an inter-terminal voltage of the detection winding; and the detection voltage Va is decreased by an amount equal to a zener voltage VZD of a zener diode Zd, and then inputted to a base of the output transistor Q4. That is, when the output transistor Q4 is in an off state, the control switching element Q3 is kept in the on state; however, in the semi-lighting state, the detection voltage Va sufficiently increases to thereby turn on the output transistor Q4, and on the basis this, the control switching element Q3 is turned off to decrease the target value. That is, the turning on of the output transistor Q4 means that the semi-lighting state is detected.

[0045] Next, to describe the example of Fig. 11, the lighting detection part 5 generates a detection voltage Va1 not by the detecting winding as in the example of Fig. 10, but by diode-based semi-wave rectification, resistor Ri-based current/voltage conversion, and capacitor based smoothing of a current (i.e., the resonant current) IL flowing into the resonant part 2 from the discharge lamp La side, and directly inputs the detection voltage Va1 to the base of the output transistor Q4, and the rest is in common with the example of Fig. 10. That is, in the semi-lighting state, the above detection voltage Va1 sufficiently increases to thereby turn on the output transistor Q4, and the turning on of the output transistor Q4 means the semi-lighting state is detected.

[0046] In any of the examples of Figs. 10 and 11, if the discharge lamp La lit in the semi-lighting state fades away to return to the extinction state, the control switching element Q3 is immediately turned on to thereby restore the target value, and along with this, the operating frequency f is decreased. However, if the transition between the semi-lighting state and the extinction state is frequently repeated, the operating frequency f becomes unstable, and thereby excessive electric stress may be placed on the respective circuit components and the respective discharge lamps La.

[0047] For this reason, the restoration of the target value as described above may be adapted to be achieved only if the extinction state continues for a predetermined delay time or more. Specifically, for example, a circuit configuration as illustrated in Fig. 12 is employed. In the example of Fig. 12, a basic configuration is in common with the example of Fig. 10; however, there are differences from the example of Fig. 10 in that, as the control switching element Q3, in place of the transistor, an n-channel MOSFET is used, and the output transistor Q4 is connected in parallel with a capacitor (hereinafter referred to as a "delaying capacitor") C4. That is, in the case where the delaying capacitor C4 is not provided, as illustrated in Fig. 13, every time the detection voltage Va falls below a sum of the zener voltage VZD of the Zener diode ZD and a base-emitter voltage Vbe necessary to turn on the output transistor Q4 (hereinafter referred to as a "switching threshold value") VZD+Vbe, the control switching element Q3 is turned off to thereby make the operating frequency f unstable. On the other hand, in the case where the delaying capacitor C4 is provided, as illustrated in Fig. 14, even if the detection voltage Va falls below the switching threshold value VZD+Vbe, until a gate-source voltage Vgs of the control switching element Q3, i.e., an inter-terminal voltage of the delaying capacitor C4 increases to reach a gate-source voltage necessary to turn on the control switching element Q3 (hereinafter referred to as an "on voltage") Von, the target value is not restored, and therefore the operating frequency f is unlikely to become unstable. Each of Figs. 13 and 14 illustrates time variations of an inter-terminal voltage (lamp voltage) VL1 of one of the discharge lamps La, which is lit, the current (lamp current) IL1 flowing through the one discharge lamp La, the inter-terminal voltage (lamp voltage) VL2 of the other (i.e., unlighted) discharge lamp La, the detection voltage Va, the gate-source voltage Vgs of the control switching element Q3, and the operating frequency f. Within a range illustrated in each of Figs. 13 and 4, the above other discharge lamp La is not lit, and therefore in the above other discharge lamp La, the lamp current IL2 remains at 0. The lamp voltages VL1 and VL2 in each of Figs. 13 and 14 are ones in which the lamp voltage VL illustrated in Fig. 6 or the like is distinguished for each of the discharge lamps La, and the resonant current IL corresponds to a sum of the above lamp currents IL1 and IL2, i.e., IL1+IL2. Also, in each of the Figs. 13 and 14, during a period from t1 to t2, the starting sweep operation is performed; timing t3 indicates timing when the semi-lighting state is started by lighting of one of the discharge lamps La; timing t3 indicates timing when the above one discharge lamp La is first lit; timing t4 indicates timing when the target value is first decreased; and timing t5 indicate timing when in the respective discharge lamps La, amplitudes of the respective lamp voltages VL1 and VL2 are stabilized. In the example of Fig. 13, the target value is repeatedly decreased and restored to thereby make the lighting of the discharge lamp La unstable, whereas in the example of Fig. 14, the target value is not restored and thereby the timing t5 when the amplitudes of the lamp voltages VL1 and VL2 are stabilized is earlier. In the above case, in the lighting detection part 5, a part from the circuit that generates the detection voltage Va to the output transistor Q4 serves as an extinction detection part, and the turning off of the output transistor Q4 means that, in other word, the transition to the extinction state is detected. Note that even by inserting an appropriate delay circuit into a stage prior to a gate terminal of the control switching element Q3, the same operation can be achieved. Such a delay circuit can be realized by a well known technique using, for example, a single stable multivibrator. Also, the above various types of variations can also be made to the example of Fig. 11, and even in this case, a part from the circuit that generates the detection voltage Va to the output transistor Q4 serves as the extinction detection part as well.

[0048] Further, instead of, as in the example of Fig. 10, changing the target value in a stepwise manner depending on whether or not the semi-lighting state is detected, the target value may be adapted to be continuously decreased as the detection voltage Va increases. For example, as illustrated in Fig. 15, the lighting detection part 5 is configured to include only a circuit that generates the detection voltage Va, and an adder Add that adds a voltage generated by detecting the electric quantity (in the example of Fig. 15, the inter-terminal voltage of the current detecting resistor Rd) and the detection voltage Va generated in the lighting detection part 5 to input a resultant voltage to the feedback terminal FB of the control part 4 is provided. In the example of Fig. 15, the detection voltage Va other than zero means that the semi-lighting state is detected. Also, as the detection voltage Va increases, the input voltage to the feedback terminal FB is increased with respect to a constant electric quantity (e.g., the resonant current IL), and therefore the above target value (e.g., the target current) of the electric quantity is substantially decreased. In the case where a plurality of types of discharge lamps La having different rated powers (i.e., different impedances) are envisaged as the discharge lamps La to be connected, the lower the impedance of each of the discharge lamps La in the semi-lighting state, the higher the lamp voltage VL of the discharge lamp La and the detection voltage Va. If the above configuration is employed, although the target value in the extinction state is sufficiently increased to the extent that, out of the discharge lamps La envisaged to be connected, one having the highest rated power can be lit, the lower the impedance of each of the discharge lamps La, the more the target value is decreased, and thereby electric stress on each of the discharge lamps La is reduced.

[0049] Also, 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 target value 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.

[0050] Further, 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 component of the resonant part 2 or a winding of the balancer T is appropriately added, a configuration where three or more discharge lamps La are lit can also be provided. In this case, preferably, the lighting detection part 5 generates an output depending on the number of lighted discharge lamps La, and the control part 4 changes the target value in a stepwise manner depending on the number of the lighted discharge lamps La. The lighting detection part 5 and the control part 4 as described above can be respectively realized by a well known technique, and therefore detailed illustration and description thereof are omitted.

[0051] Any of the above-described various types of discharge lamp lighting devices can be used for an illumination fixture 6 as illustrated in Fig. 16. To describe in detail, the illumination fixture 6 in Fig. 16 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 and resonant part 2; 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 that holds 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]

[0052]

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 resonant part that is connected to each of the discharge lamps and constitutes a resonant circuit along with each of the discharge lamps;
   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 thereby supply AC power to the respective discharge lamps from the resonant part;
an electric quantity detection part that detects one electric quantity correlated to an inter-terminal voltage of each of the discharge lamps;
a control part that performs feedback control of a frequency of operation of the drive part so as to bring the electric quantity detected by the electric quantity detection part close to a predetermined target value; 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 changes the target value so as to decrease an effective value of the inter-terminal voltage of each of the discharge lamps.

2. The discharge lamp lighting device according to claim 1, wherein:

the resonant part includes one LC resonant circuit; and
a balancer having a plurality of windings each having one terminal connected to one terminal of a corresponding one of the discharge lamps and the other terminal connected to the resonant part is provided, the plurality of windings being mutually magnetically coupled.

3. The discharge lamp lighting device according to claim 2, 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.

4. The discharge lamp lighting device according to claim 2 or 3, wherein
the electric quantity detection part detects, as the electric quantity, an inter-terminal voltage of any component of the resonant part.

5. The discharge lamp lighting device according to any one of claims 1 to 3, wherein
the electric quantity detection part detects, as the electric quantity, currents flowing through the switching elements of the switching part.

6. The discharge lamp lighting device according to any one of claims 1 to 5, wherein
the lighting detection part compares an effective value of an input current from a side of the discharge lamps to the resonant part with a predetermined switching threshold value, and when the effective value of the input current exceeds the switching threshold value, detects the start of the semi-lighting state.

7. The discharge lamp lighting device according to any one of claims 2 to 4, wherein:

the balancer has a detecting winding; and
when a detection voltage obtained by rectifying and smoothing 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.

8. The discharge lamp lighting device according to any one of claims 2 to 4, wherein:

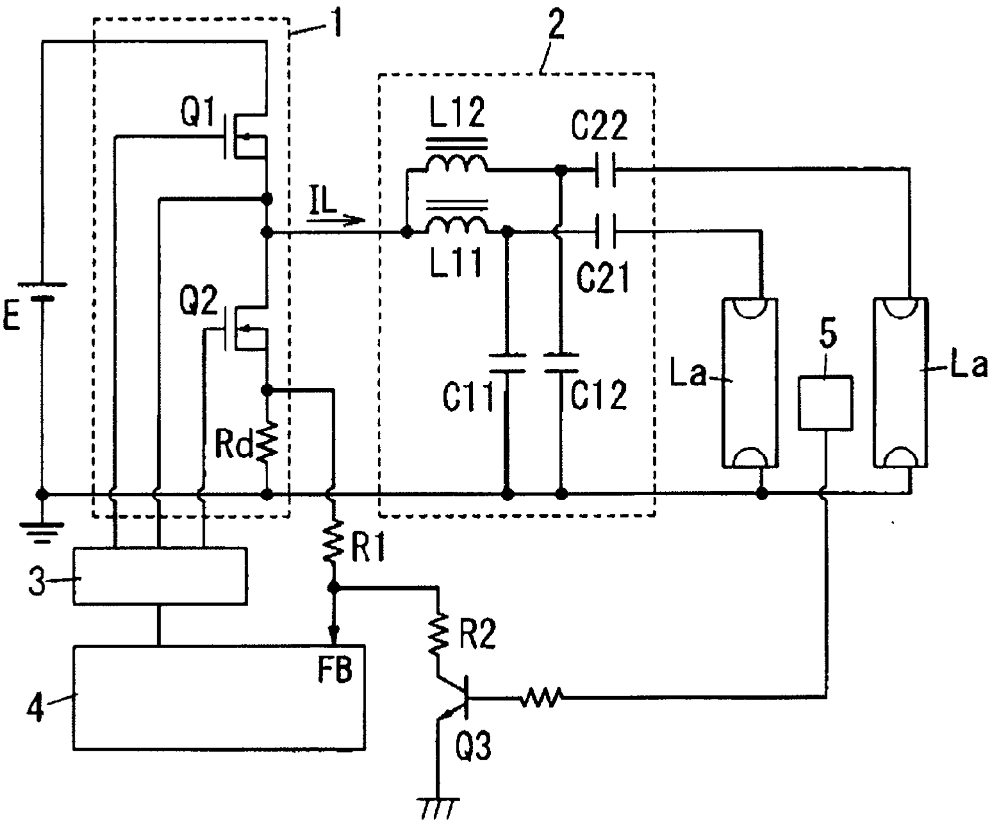
the balancer has a detecting winding;
the lighting detection part generates a detection voltage by rectifying and smoothing an inter-terminal voltage of the detecting winding; and
the control part decreases the target value as the detection voltage increases.

9. The discharge lamp lighting device according to any one of claims 1 to 7, comprising
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 the semi-lighting state.

10. An illumination fixture comprising:

the discharge lamp lighting device according to any one of claims 1 to 9; 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
Q1, Q2: Switching element

Figure 2

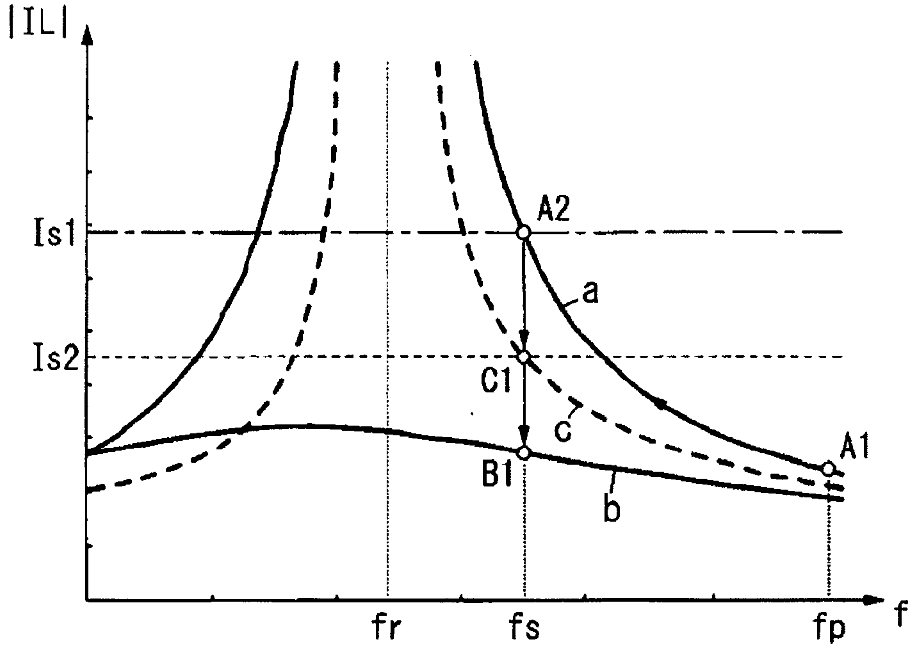


Figure 3

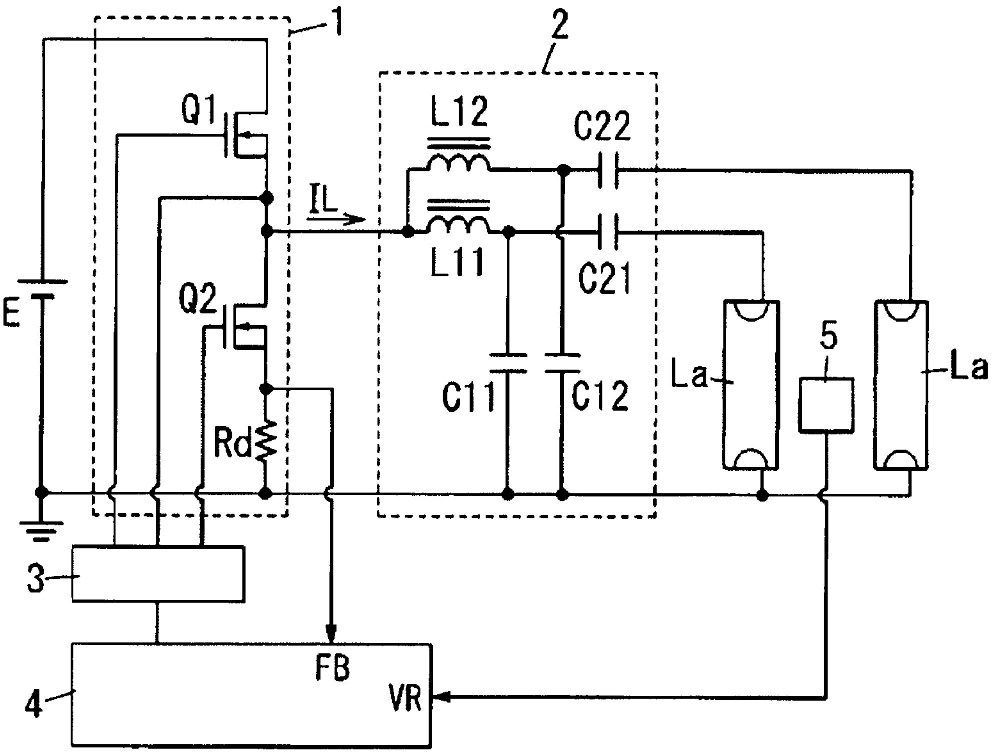


Figure 4

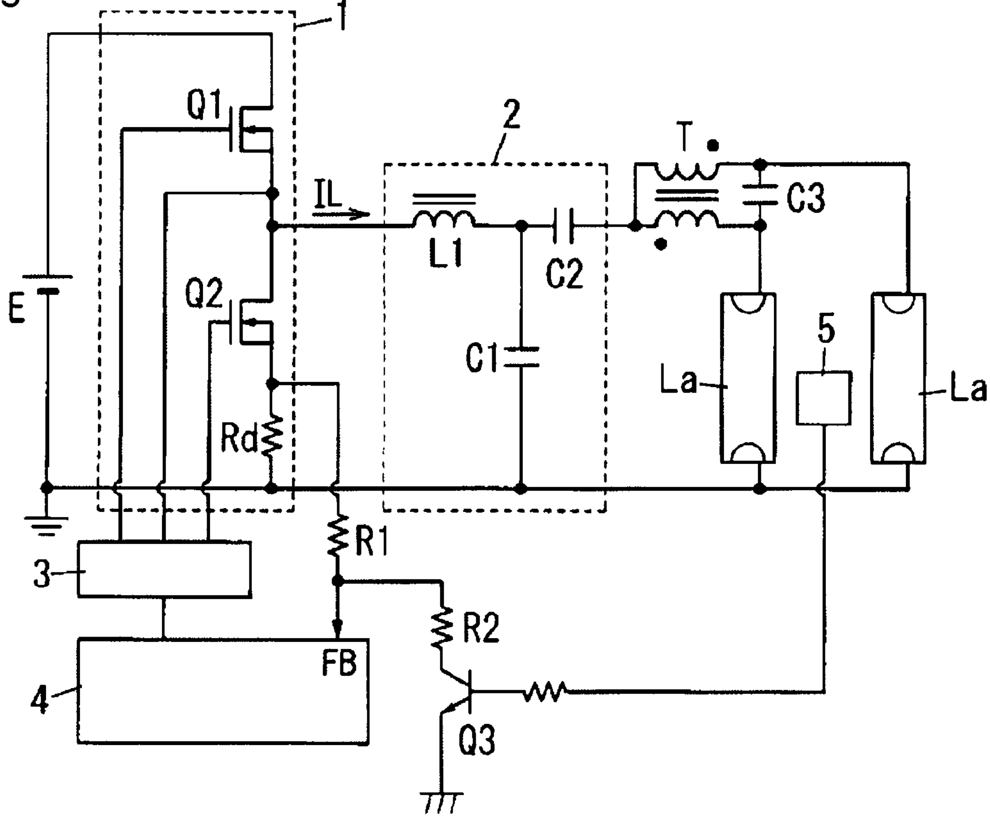


Figure 5

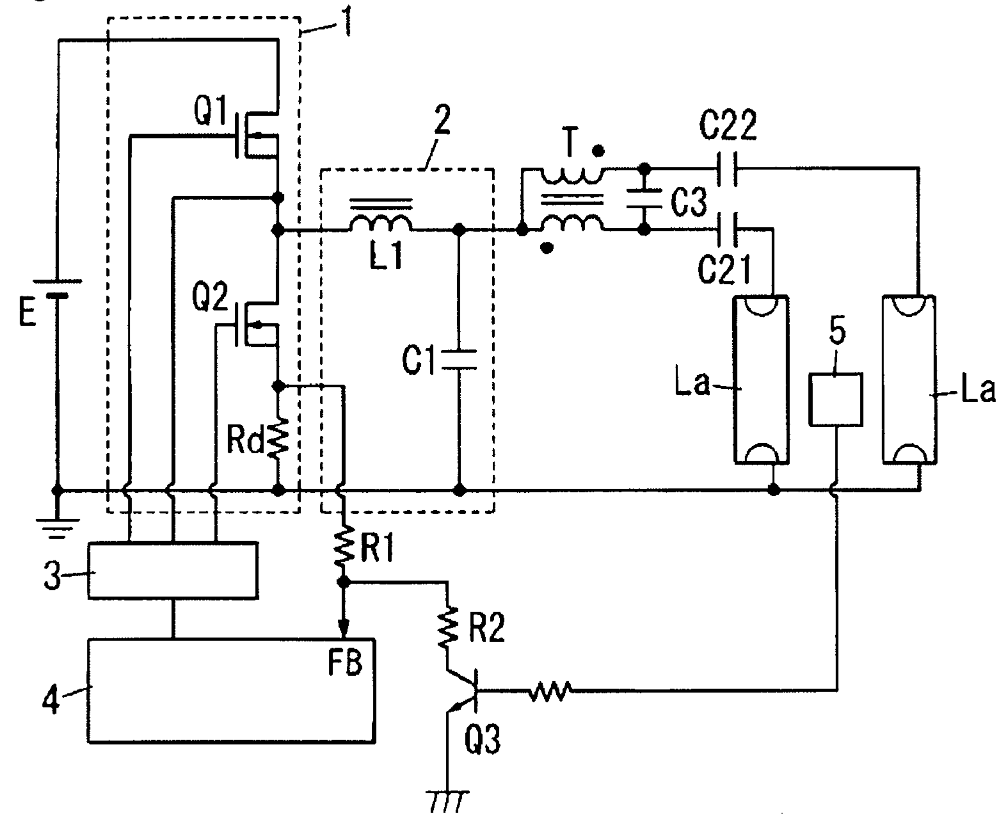


Figure 6

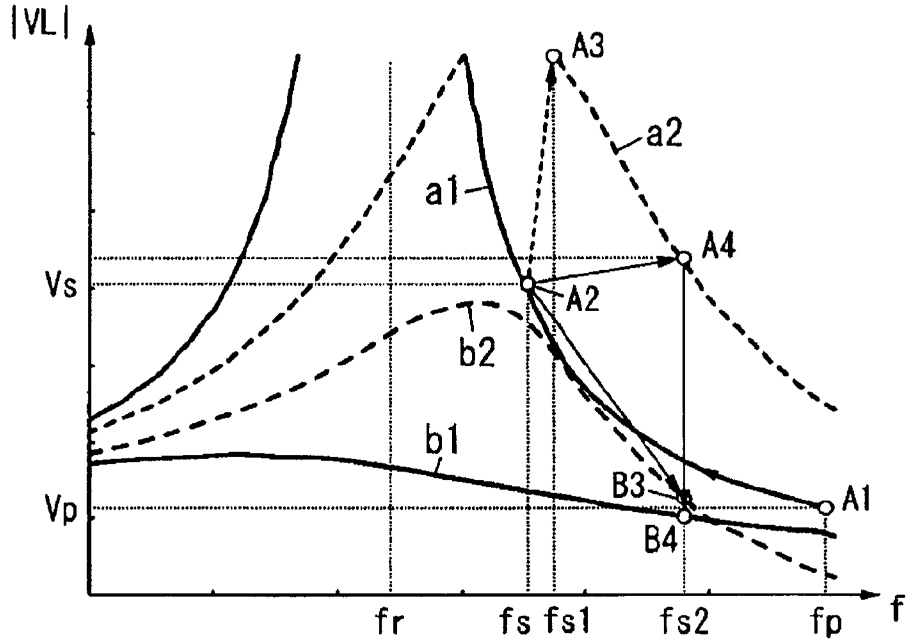


Figure 7

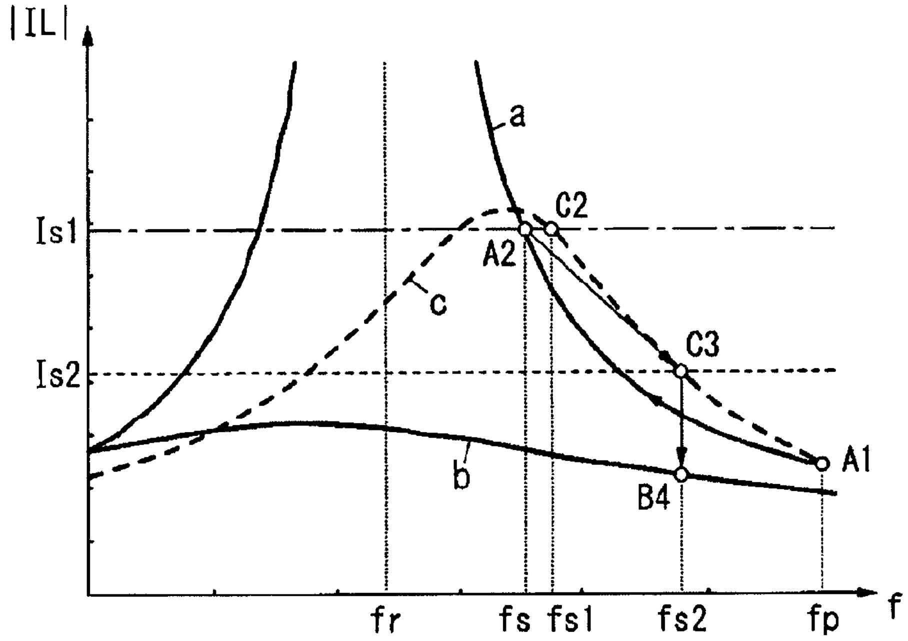


Figure 8

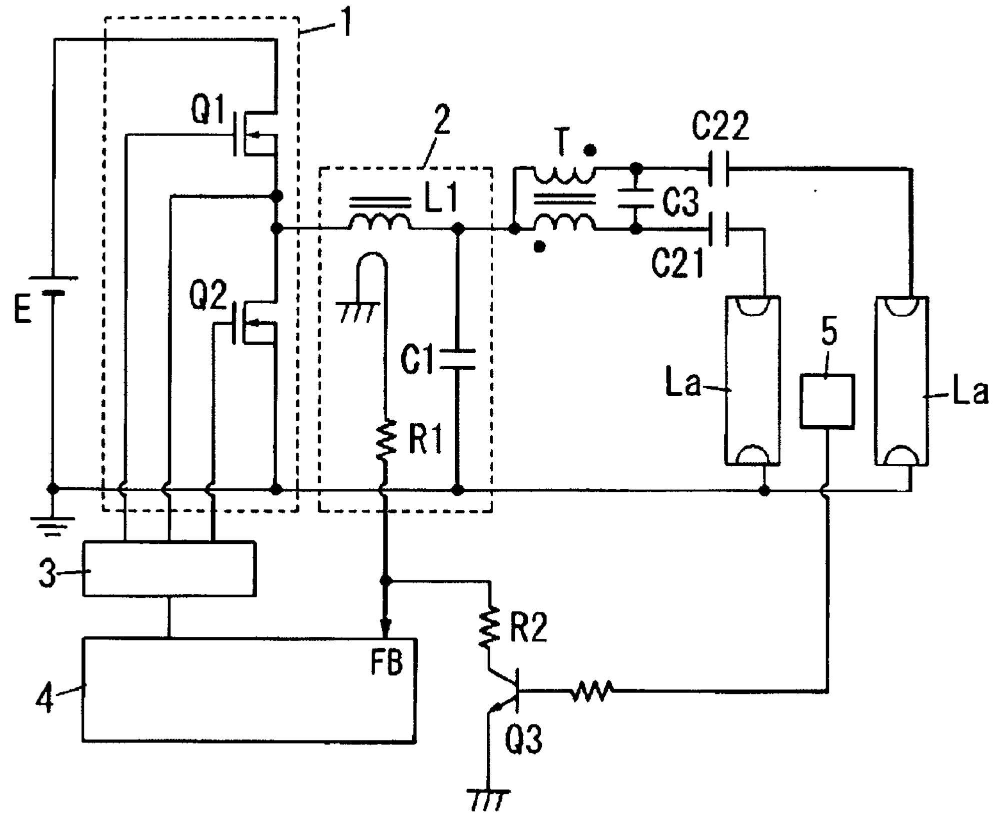


Figure 9

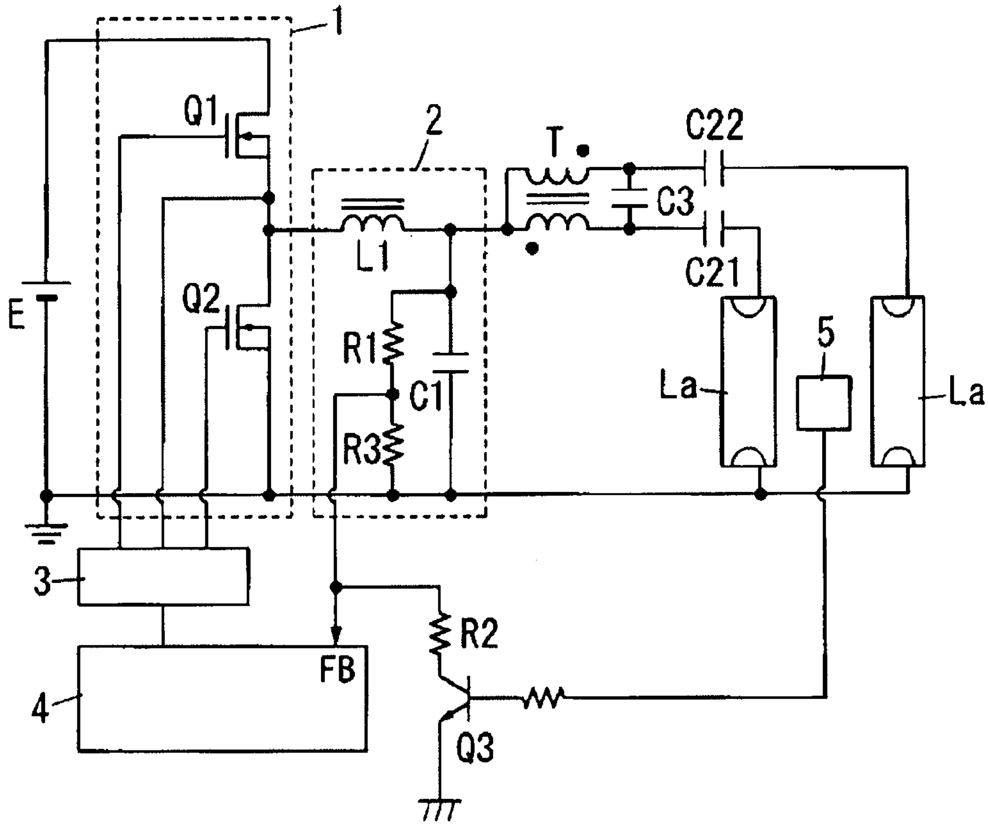


Figure 10

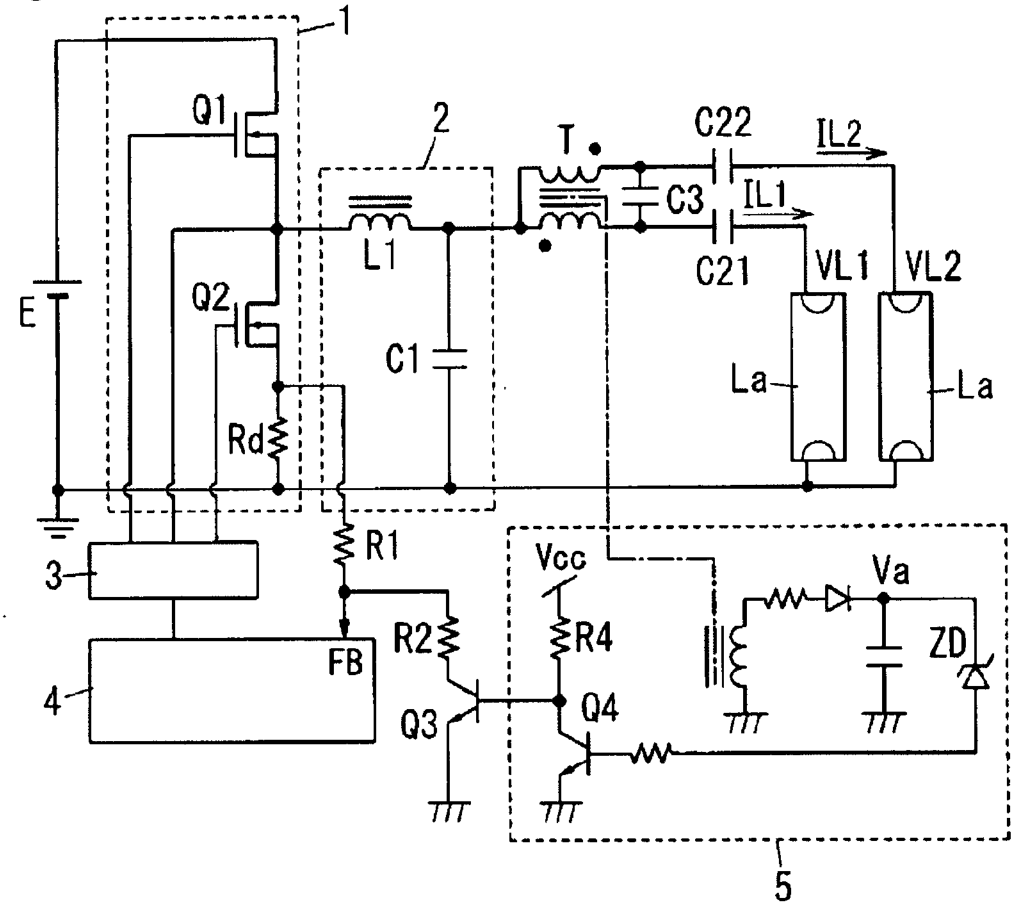

1
Q1
2
T
C22
IL2
C3
IL1
L1
C21
VL1
VL2
Q2
E
C1
La
La
Rd
R1
Vcc
Va
3
R2
R4
ZD
FB
4
Q4
Q3
5

Figure 11

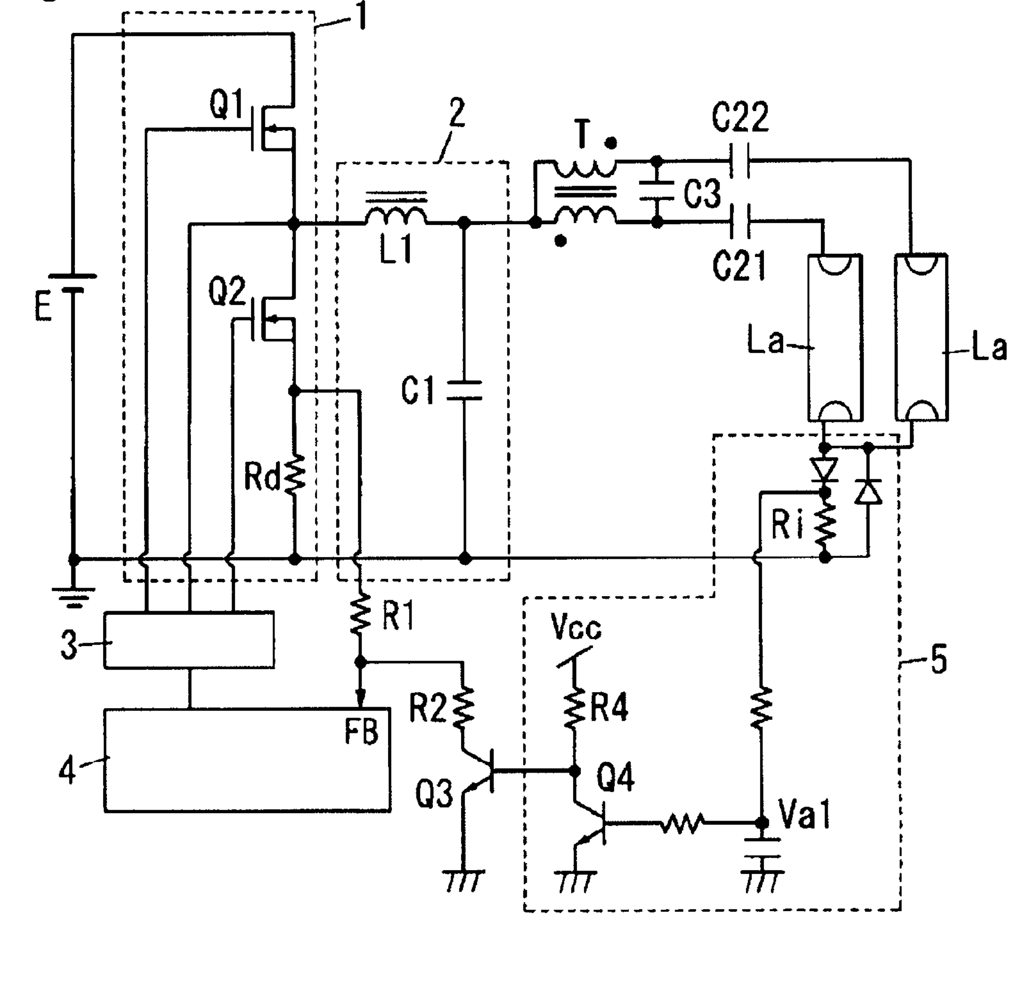
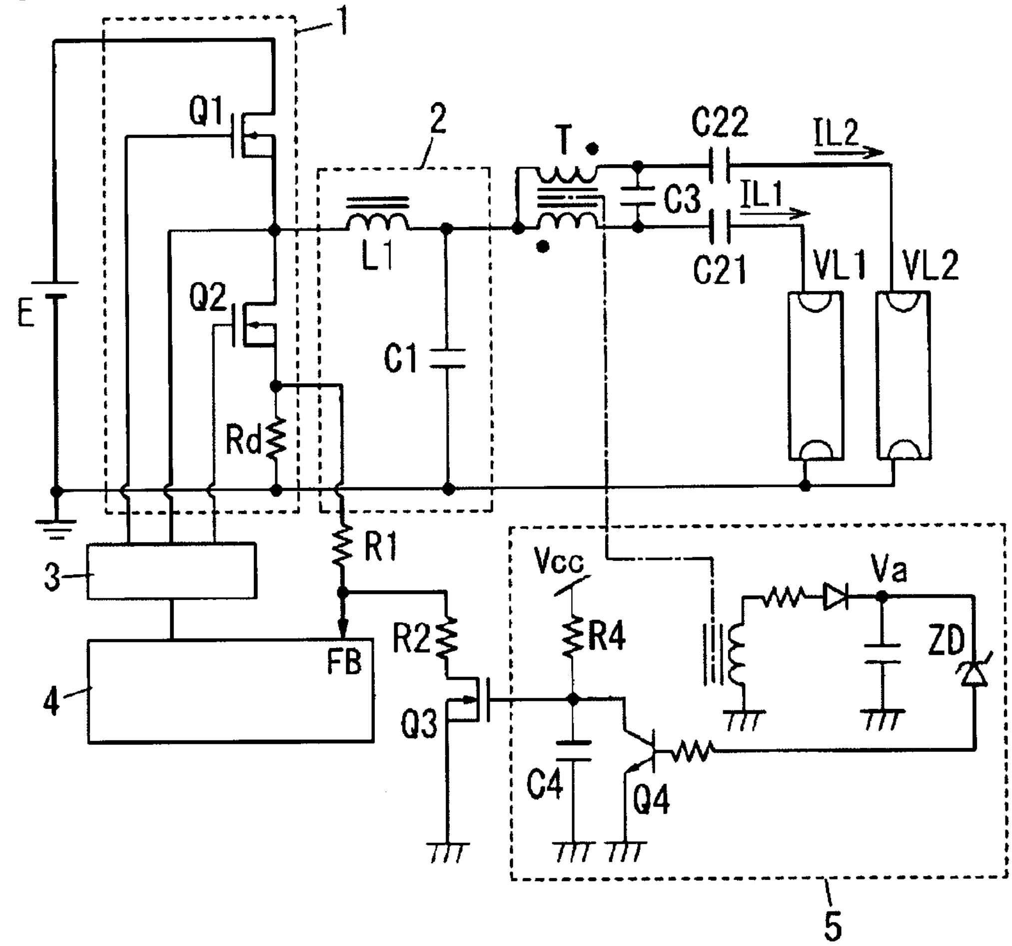


Figure 12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Q1
2
T
C22
IL2
C3
IL1
L1
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VL1
VL2
Q2
E
C1
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Q3
C4
Q4
5

Figure 13

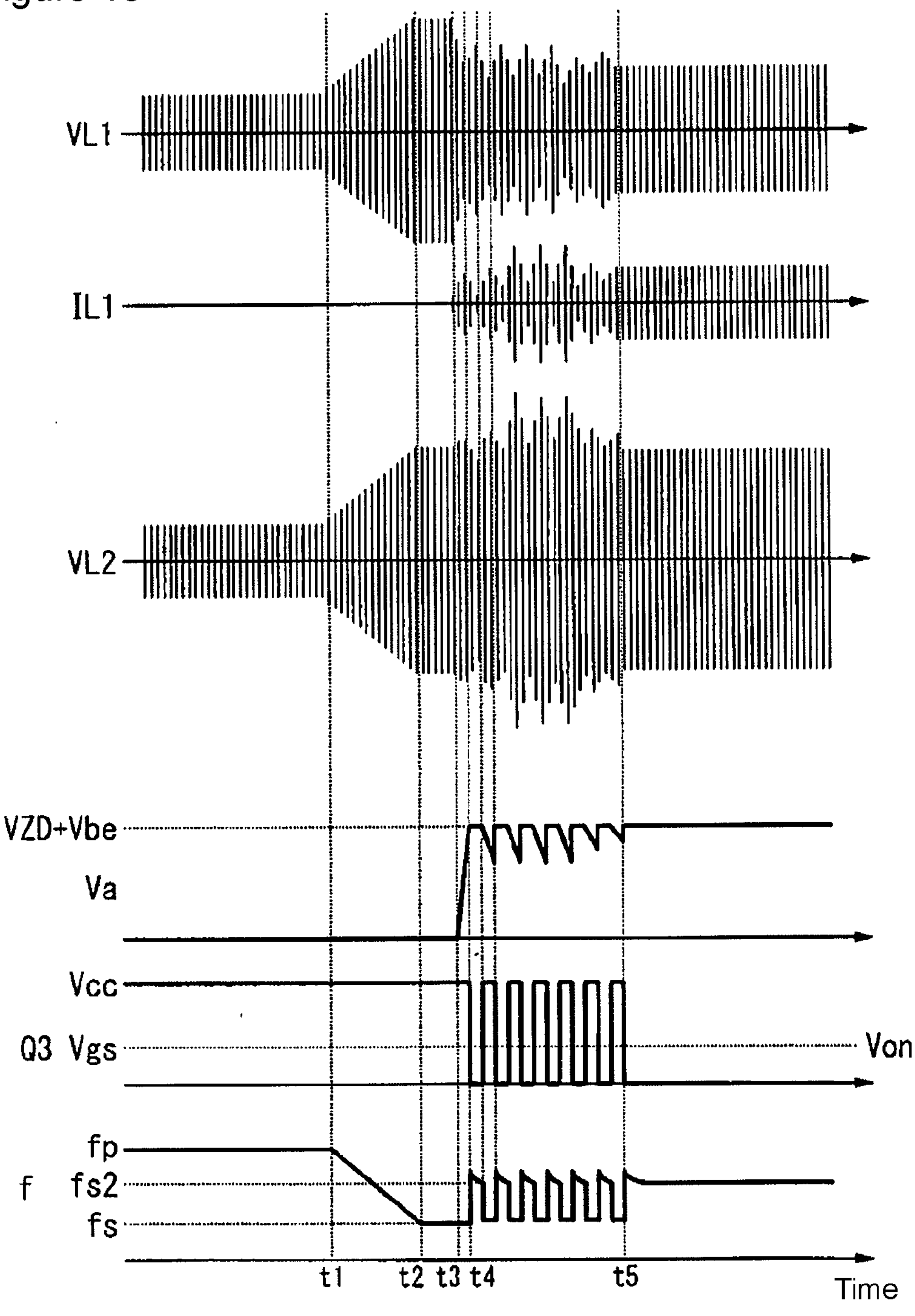

VL1
IL1
VL2
VZD+Vbe
Va
Vcc
Q3 Vgs
Von
fp
f fs2
fs
t1
t2
t3
t4
t5
Time

Figure 14

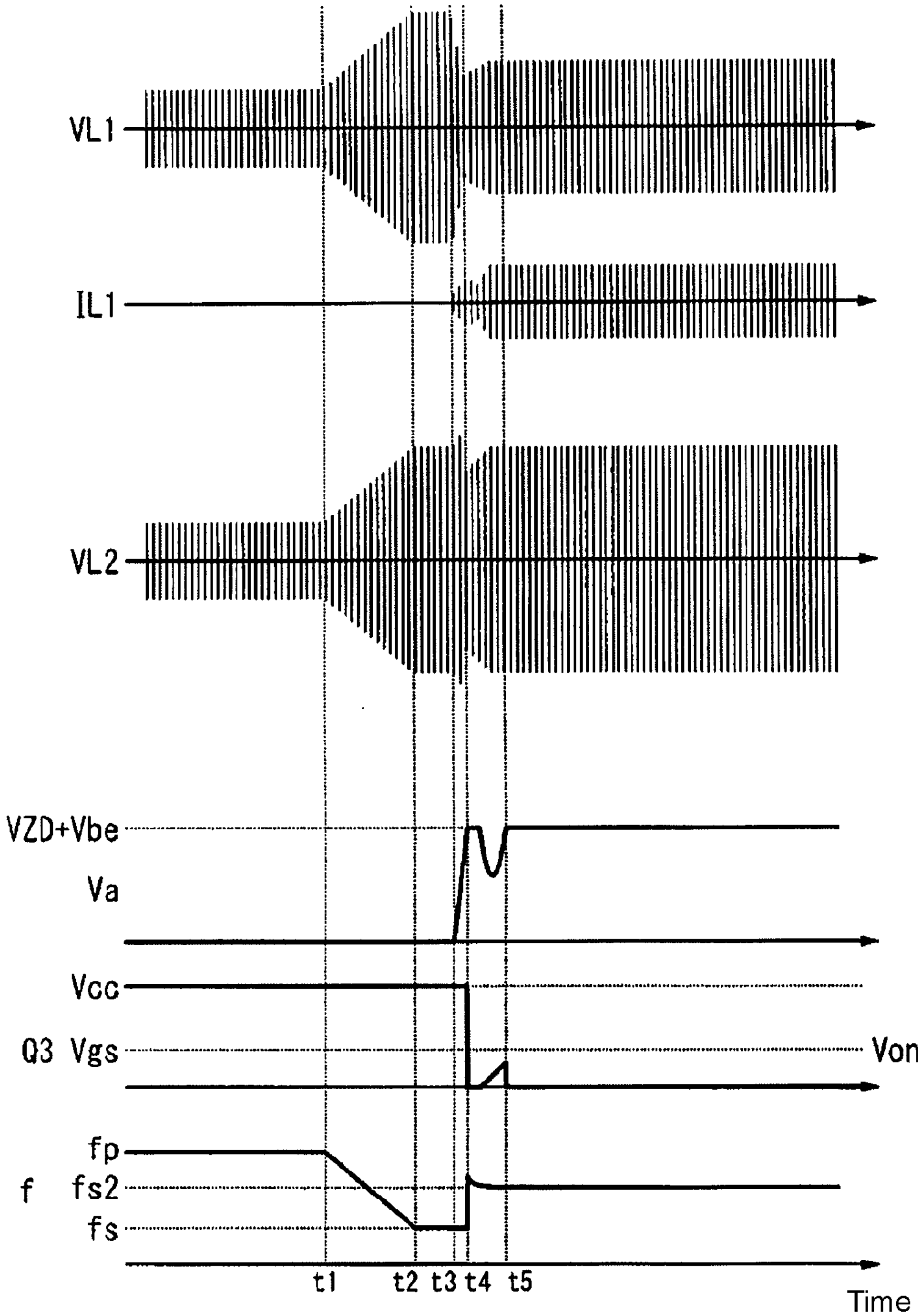

VL1
IL1
VL2
VZD+Vbe
Va
Vcc
Q3 Vgs
Von
fp
f
fs2
fs
t1
t2
t3
t4
t5
Time

Figure 15

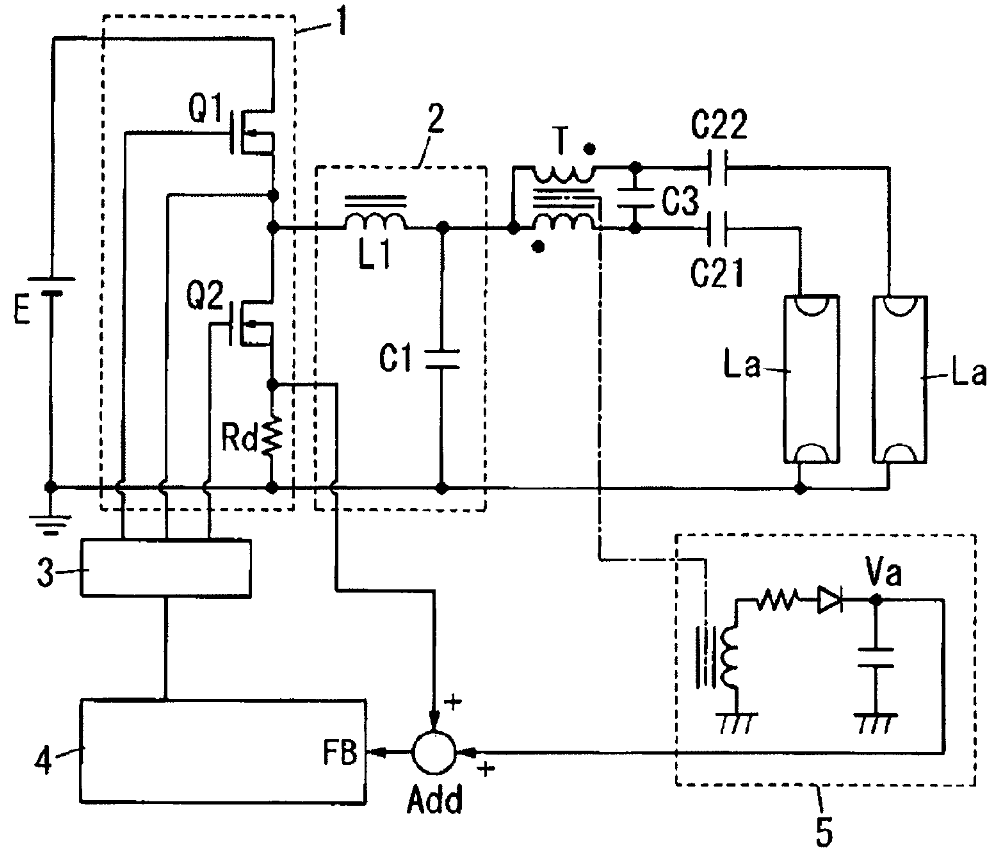


Figure 16

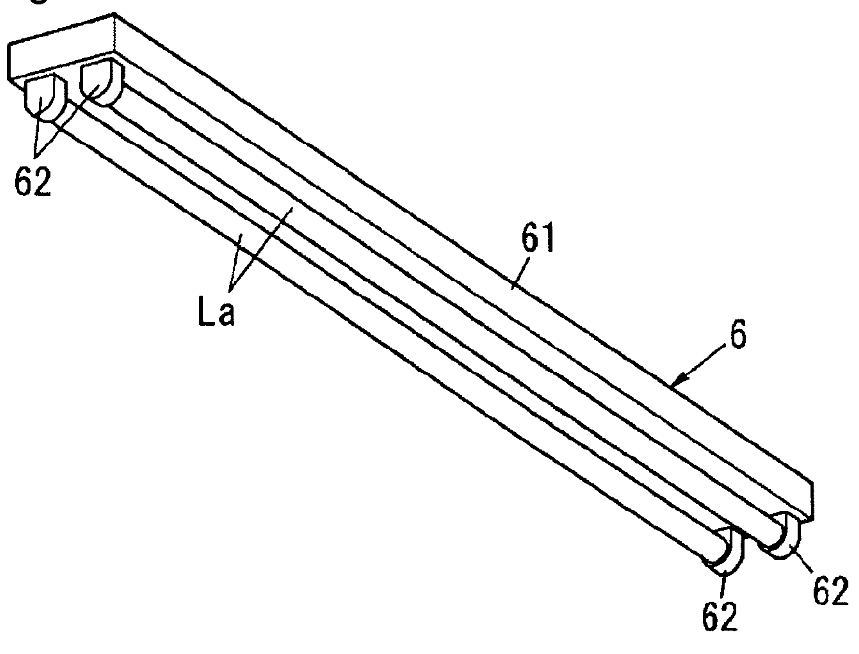


Figure 17

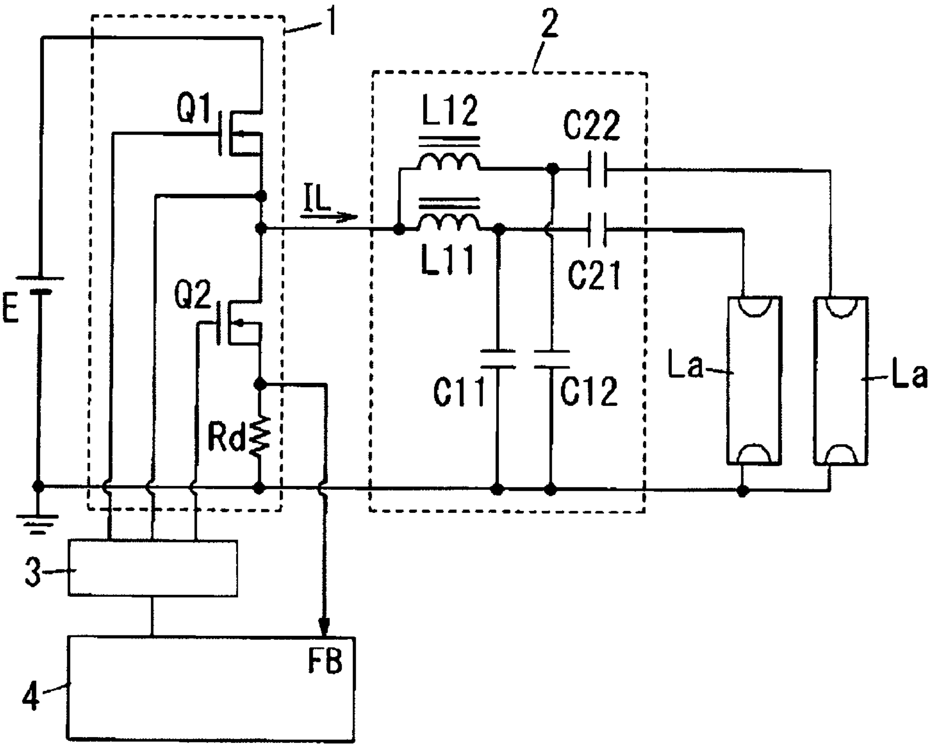


Figure 18

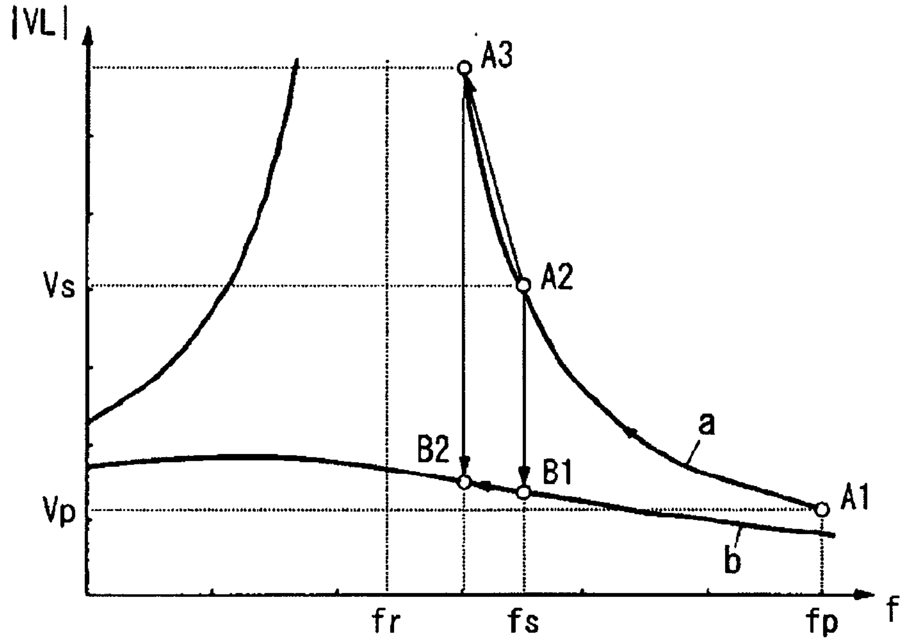
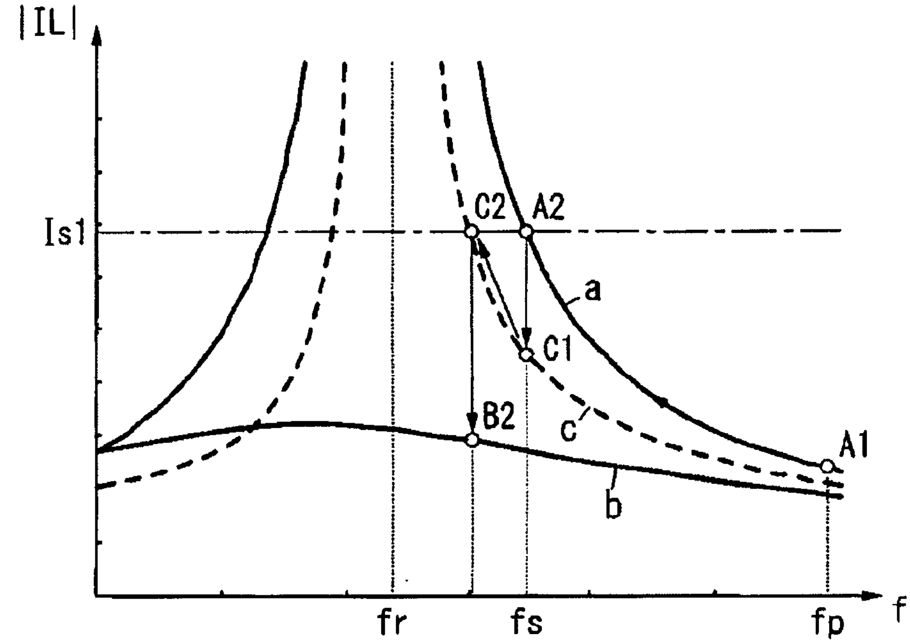


Figure 19



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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