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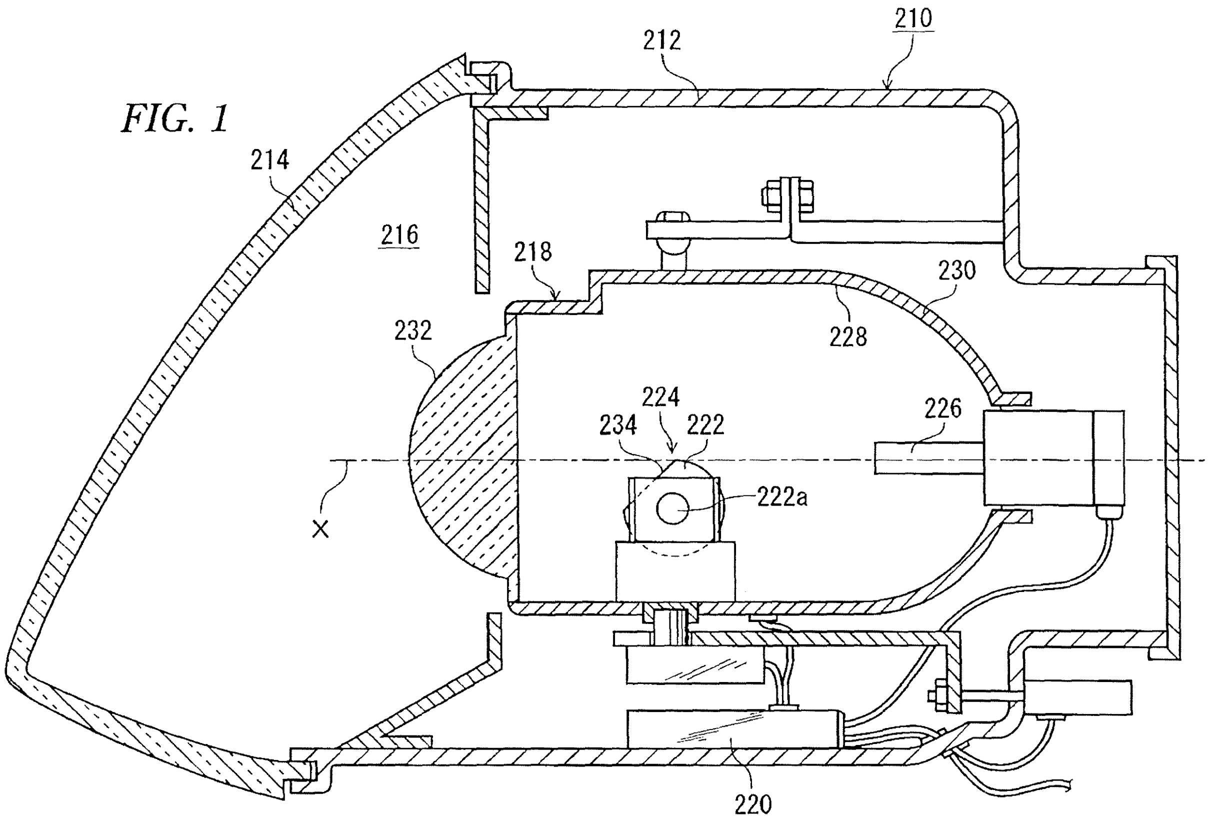
(54) Discharge lamp lighting circuit

(57) A discharge lamp lighting circuit 100 supplies power to a discharge lamp 226 used as a light source of a vehicle lighting device capable of switching between a first state and a second state by light distribution change means. A light distribution pattern of the second state is different from a light distribution pattern of the first state. The power supplied to the discharge lamp 226 is changed at a timing of switching from the first state to the second state.

FIG. 1



EP 2 420 407 A1

Description

FIELD

[0001] Apparatuses consistent with the present invention relate to a discharge lamp lighting circuit.

BACKGROUND

[0002] In general, light distribution patterns formed ahead of a vehicle by light emitted from a vehicle lighting device such as a headlamp of a vehicle or the like include a light distribution pattern for a driving beam (also referred to as a high beam) and a light distribution pattern for a passing beam (also referred to as a low beam). As a headlamp, there is a headlamp of the type called a two-lamp type headlamp in which both of the light distribution patterns are realized by using the same light source.

[0003] As the light source used in the headlamp mentioned above, a discharge lamp such as a metal halide lamp or the like is used in recent years instead of a halogen lamp having a filament. The discharge lamp has high light emission efficiency and long life when compared with the halogen lamp, but requires several ten to several hundred Volts (V) as a drive voltage so that the discharge lamp can not be driven directly by a vehicle-mounted battery of 12 V or 24 V, and therefore requires a discharge lamp lighting circuit (also referred to as a ballast).

[0004] On the other hand, in order to achieve a reduction in the cost of the headlamp, a reduction in the power of the discharge lamp as the light source has been promoted. In many vehicle discharge lamps currently distributed on the market, input power at the time of steady operation is about 35 watts (W), and the input power at the time of steady operation of the currently available latest low power discharge lamp is not more than 30 W, and in particular about 25 W.

[0005] JP-A-2001-080411 discloses a vehicle discharge lamp apparatus including a lighting circuit which performs lighting control of a discharge lamp for driving beam emission and a discharge lamp for passing beam emission which have the same rating.

[0006] When a high beam and a low beam are switched in a two-lamp type headlamp, for example, a light-blocking state in the headlamp is mechanically changed. In general, in the case of the low beam, light from the discharge lamp is blocked in a larger amount than in the case of the high beam. Herein, when the above-described low power discharge lamp is used as the light source, the luminous flux of the light emitted from the discharge lamp is reduced due to its low power.

[0007] In order to obtain the light of the luminous flux required for the high beam even when the low power discharge lamp is used, it is considered that the amount of blocked light in the high beam is reduced in accordance with the reduction in the luminous flux, or the light is not blocked. However, these countermeasures have limitations, and it is difficult to use the lower power discharge lamp in the present situation.

SUMMARY

[0008] The present invention has been achieved in view of the above-described situation, and an object thereof is to provide a discharge lamp lighting circuit which may realize power control in accordance with switching of a state of a vehicle lighting device.

[0009] An aspect of the present invention relates to a discharge lamp lighting circuit. The discharge lamp lighting circuit is a discharge lamp lighting circuit that supplies power to a discharge lamp used as a light source of a vehicle lighting device capable of switching between a first state and a second state by light distribution change means, wherein a light distribution pattern of the second state is different from a light distribution pattern of the first state, and wherein the power supplied to the discharge lamp is changed at a timing of switching from the first state to the second state.

[0010] According to this aspect, it may become possible to perform control of supplied power in accordance with the switching of the state in the vehicle lighting device.

[0011] It is to be noted that any arbitrary combinations of the above-mentioned components and any changes in the component and the expression of the present invention among a device, a method, and a system are also effective as aspects of the present invention.

[0012] According to the present invention, it may be possible to realize power control in accordance with the switching of the state of the vehicle lighting device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] A general configuration that implements the various features of embodiments of the present invention will be described with reference to the drawings. The drawings and the associated descriptions are provided to illustrate embodiments of the invention and should not limit the scope of the invention.

FIG. 1 is a schematic cross-sectional view showing an internal structure of a headlamp unit including a discharge lamp lighting circuit according to an embodiment;
FIG. 2 is a circuit diagram showing a configuration of the discharge lamp lighting circuit according to the embodiment and members connected thereto;
FIG. 3 is a circuit diagram showing a configuration of a lighting control circuit of FIG. 2;
FIG. 4 is a graph showing an illustrative time-varying change of a luminous flux of a discharge lamp and lamp power supplied to the discharge lamp;
FIG. 5 is a waveform diagram showing a rising waveform of the luminous flux measured by using the discharge lamp lighting circuit of FIG. 2;

FIG. 6 is a circuit diagram showing a configuration of an adjustment circuit according to a modification; and

FIG. 7 is a waveform diagram showing a rising waveform of the luminous flux measured by using a discharge lamp lighting circuit including the adjustment circuit according to the modification.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0014] The description will be given hereinbelow of the present invention based on a preferred embodiment with reference to the drawings. The same or equivalent components, members, and signals shown in the individual drawings are designated by the same reference numerals, and the repeated description thereof will be omitted as appropriate. In addition, in the individual drawings, a part of members which are not important in terms of the description will be omitted.

[0015] In the present specification, "a state where a member A is connected to a member B" includes the case where the member A and the member B are indirectly connected to each other via another member which does not exert an effect on an electrically connected state in addition to the case where the member A and the member B are physically and directly connected to each other. Similarly, "a state where a member C is provided between a member A and a member B" includes the case where the member A and the member C, or the member B and the member C are indirectly connected to each other via another member which does not exert an effect on the electrically connected state in addition to the case where the member A and the member C, or the member B and the member C are directly connected to each other.

[0016] FIG. 1 is a schematic cross-sectional view showing an internal structure of a headlamp unit 210 including a discharge lamp lighting circuit 100 according to the present embodiment. The headlamp unit 210 is a vehicle lighting device mounted on a vehicle. FIG. 1 shows a cross section when the headlamp unit 210 cut along a vertical plane including an optical axis X of the lighting device is viewed from the left side of the lighting device. The headlamp unit 210 is one of units of a two-lamp type headlamp which realizes a high-beam state and a low-beam state by using the same light source.

[0017] The headlamp unit 210 has a lighting chamber 216 formed of a lamp body 212 having an opening portion in the forward direction of a vehicle and a transparent cover 214 covering the opening portion of the lamp body 212. In the lighting chamber 216, a lighting unit 218 which emits light in the forward direction of the vehicle is accommodated.

[0018] The lighting unit 218 is configured of a shade mechanism 224 including a rotational shade 222, a discharge lamp 226 as a light source, a lamp housing 230 supporting a reflector 228 on an inner wall thereof, and a projection lens 232. The discharge lamp 226 may be a mercury-free high intensity discharge lamp (HID lamp) having input power at the time of steady operation of 35 W which is currently prevalent as a vehicle discharge lamp. Alternatively, the discharge lamp 226 may also be a low power discharge lamp having input power at the time of steady operation lower than that of the above-described high intensity discharge lamp such as a ceramic discharge lamp or the like. For example, the discharge lamp 226 may be the ceramic discharge lamp having input power at the time of steady operation of 25 W.

[0019] The reflector 228 reflects light emitted from the discharge lamp 226. Subsequently, a part of the light from the discharge lamp 226 and the light reflected by the reflector 228 is guided to the projection lens 232 via the rotational shade 222 configuring the shade mechanism 224.

[0020] The rotational shade 222 is a cylindrical member rotated about a rotational shaft 222a by a shade rotating motor. In addition, the rotational shade 222 has a notched portion 234 obtained by notching a part thereof in an axial direction, and holds a plurality of tabular shade plates on an outer peripheral surface other than the notched portion 234. The rotational shade 222 is capable of moving the notched portion 234 or any one of the shade plates to a position on a rear focal surface including a rear focal point of the projection lens 232 in accordance with a rotational angle thereof. Subsequently, there is formed a light distribution pattern in conformity with the shape of a ridge portion of the shade plate positioned on the optical axis X in accordance with the rotational angle of the rotational shade 222. For example, by blocking a part of light emitted from the discharge lamp 226 by moving any one of the shade plates of the rotational shade 222 onto the optical axis X, there is formed a low-beam light distribution pattern or a light distribution pattern including features of the low-beam light distribution pattern in a part. Further, by not blocking the light emitted from the discharge lamp 226 by moving the notched portion 234 onto the optical axis X, a high-beam light distribution pattern is formed.

[0021] The rotational shade 222 can be rotated using, e.g., a motor drive, and by controlling the rotation amount of the motor, the shade plate or the notched portion 234 for forming a desired light distribution pattern is moved onto the optical axis X.

[0022] The description returns to FIG. 1.

[0023] The projection lens 232 is positioned on the optical axis X, and the discharge lamp 226 is disposed at a position on the rearward side of the rear focal surface of the projection lens 232. The projection lens 232 is formed of a flat convex aspherical lens having a convex forward surface and a flat rearward surface, and projects a light source image formed on the rear focal surface onto a virtual vertical screen forward of the lighting unit 218 as a reversed image.

[0024] On the inner wall surface of the lighting chamber 216, e.g. , at a position below the lighting unit 218, there is disposed a lighting unit control section 220 which performs turning on/off control of the lighting unit 218 and formation control of the light distribution pattern. The lighting unit control section 220 includes a discharge lamp lighting circuit 100 (described later) according to the embodiment and a light distribution state switching circuit (not shown).

[0025] The light distribution state switching circuit switches the state of the headlamp unit 210 between the high-beam state and the low-beam state in accordance with a Hi/Lo switching signal from the outside. In the high-beam state of the headlamp unit 210, light emitted from the headlamp unit 210 forms the high-beam light distribution pattern. In the low-beam state of the headlamp unit 210, the light emitted from the headlamp unit 210 forms the low-beam light distribution pattern.

[0026] More specifically, when the Hi/Lo switching signal is asserted (is at high level), the light distribution state switching circuit controls the motor of the shade mechanism 224 such that the high-beam light distribution pattern is formed. When the Hi/Lo switching signal is negated (is at low level), the light distribution state switching circuit controls the motor of the shade mechanism 224 such that the low-beam light distribution pattern is formed.

[0027] It is to be noted that, although the high-beam state and the low-beam state are switched using mechanical operations in the headlamp unit 210 in the present embodiment, the high-beam state and the low-beam state may be switched using other light distribution changing means. For example, the states may be switched by using a lens of which a refractive index is changed by applying an electrical signal thereto, or may also be switched by using a Micro Electro Mechanical Systems (MEMS) mirror.

[0028] FIG. 2 is a circuit diagram showing a configuration of the discharge lamp lighting circuit 100 according to the embodiment and other members connected thereto. The discharge lamp lighting circuit 100 supplies power to the discharge lamp 226 used as the light source of the headlamp unit 210. The discharge lamp lighting circuit 100 is connected to a vehicle-mounted battery (hereinbelow simply referred to as a battery) 6 and a power supply switch 8.

[0029] The battery 6 generates a direct current battery voltage (power supply voltage) Vbat of 12 V (or 24 V). The power supply switch 8 is a relay switch provided to control ON/OFF of the lighting of the discharge lamp 226, and is provided in series with the battery 6. When the power supply switch 8 is turned ON, the battery voltage Vbat is supplied to the discharge lamp lighting circuit 100 from the battery 6.

[0030] The discharge lamp lighting circuit 100 boosts the smoothed battery voltage Vbat, converts the battery voltage into alternating current, and supplies the battery voltage to the discharge lamp 226. The discharge lamp lighting circuit 100 includes a DC/DC converter CONV, a lighting control circuit 10, a starter circuit 20, an inverter circuit 30, an input capacitor Cin, and a current detection resistor Rd.

[0031] The input capacitor Cin is provided in parallel with the battery 6, and smoothes the battery voltage Vbat. More specifically, the input capacitor Cin is provided in the vicinity of an input transformer 14, and fulfils a function of smoothing a voltage in response to a switching operation of the DC/DC converter CONV.

[0032] The DC/DC converter CONV boosts the battery voltage Vbat. The DC/DC converter CONV is an insulating type switching regulator, and includes the input transformer 14, an output diode D1, an output capacitor Co, and a first switching element M1.

[0033] A primary winding L1 of the input transformer 14 and the first switching element M1 are provided in series between an input terminal Pin of the DC/DC converter CONV and a ground terminal (GND) in parallel with the input capacitor Cin. For example, the first switching element M1 is configured of an N-channel Metal Oxide Semiconductor Field Effect Transistor (MOSFET). One end of a secondary winding L2 of the input transformer 14 is grounded, and the other end thereof is connected to an anode of the output diode D1. The output capacitor Co is provided between a cathode of the output diode D1 and the ground terminal.

[0034] A control terminal (gate) of the first switching element M1 is connected to a first terminal P1 of the lighting control circuit 10. To the control terminal of the first switching element M1, a control pulse signal S1 of a drive frequency f 1 is applied. In a steady lighting state, the drive frequency f1 is, e.g., 400 kHz. The first switching element M1 is turned ON when the control pulse signal S1 is at high level, and the first switching element M1 is turned OFF when the control pulse signal S1 is at a low level.

[0035] The inverter circuit 30 converts a direct current output voltage Vo boosted by the DC/DC converter CONV into an alternating current voltage of a lighting frequency f 2, and supplies the alternating current voltage to the discharge lamp 226. As the inverter circuit 30, known inverter circuits such as, e.g., an H-bridge circuit and the like are used.

[0036] The lighting frequency f 2 is set to be lower than the drive frequency f 1. The lighting frequency f 2 is set to preferably not more than 10 kHz, further preferably about 250 Hz to about 750 Hz, and is set to 312.5 Hz in the present embodiment. A reciprocal of the lighting frequency f 2 is referred to as a lighting period T 2 (= 1/f 2 = 3.2 ms).

[0037] The current detection resistor Rd is provided on a path of a lamp current IL flowing to the discharge lamp 226. In the circuit of FIG. 2, the current detection resistor Rd is provided on a ground wiring which connects the DC/DC converter CONV and the inverter circuit 30. In the current detection resistor Rd, a voltage drop Vd in proportion to the lamp current IL occurs.

[0038] The starter circuit 20 is provided to cause breakdown of the discharge lamp 226. The starter circuit 20 includes a starter transformer 22 and a pulse generation circuit 28. The pulse generation circuit 28 applies a pulse voltage having an amplitude of 400 V to 1 kV to a primary winding 24 of the starter transformer 22. As a result, on the side of a secondary winding 26, a high voltage pulse (e.g. , 20 kV) in correspondence to a winding ratio of the starter transformer 22 is generated, and is applied to the discharge lamp 226. As a result, the breakdown of the discharge lamp 226 is caused, and discharge is started.

[0039] The lighting control circuit 10 includes a functional Integrated Circuit (IC) for controlling the discharge lamp lighting circuit 100.

[0040] The lighting control circuit 10 monitors the output voltage Vo and the lamp current IL, and controls a duty ratio of the control pulse signal S1 such that power supplied to the discharge lamp 226 approaches desired target power. To the lighting control circuit 10, a Hi/Lo switching signal S2 is supplied from the outside. The lighting control circuit 10 performs control of increasing the power supplied to the discharge lamp 226 at the timing of switching from the low-beam state to the high-beam state in the headlamp unit 210. That is, when detecting a rising edge in the Hi/Lo switching signal S2, the lighting control circuit 10 adjusts the duty ratio of the control pulse signal S1 to increase the output voltage Vo of the DC/DC converter CONV.

[0041] In addition, the lighting control circuit 10 is configured such that a design maximum value of power supplied to the discharge lamp 226 in the high-beam state and a design maximum value of power supplied to the discharge lamp 226 in the low-beam state are equal to each other. The design maximum value of the power supplied to the discharge lamp 226 is a reference value of the power supplied to the discharge lamp 226. In other examples, an average value or a maximum value of power may be used as the reference value, or a reference value of a lamp voltage or a lamp current indicative of the power supplied to the discharge lamp 226 may also be used.

[0042] Further, a time period in which the power supplied to the discharge lamp 226 takes the maximum value from power input to steady lighting corresponds to a time period immediately after the lighting of the discharge lamp 226, i.e., a given transient time period since the start of supply of the power to the discharge lamp 226 by the discharge lamp lighting circuit 100. Since the lighting control circuit 10 is configured such that the design maximum value of the power in the high-beam state and that in the low-beam state are equal to each other, the power supplied to the discharge lamp 226 is not substantially changed even when the switching of the state of the headlamp unit 210 is performed during the above-described transient time period.

[0043] FIG. 3 is a circuit diagram showing a configuration of the lighting control circuit 10. Although the lighting control circuit 10 includes other members for causing the discharge lamp lighting circuit 10 to function in addition to members shown in FIG. 3, the members are omitted in FIG. 3 for clearer description.

[0044] The lighting control circuit 10 includes a state detection circuit 102, a timing circuit 104, an adjustment circuit 106, a reference voltage source 108, an error amplifier 110, a saw-tooth wave generation circuit 112, a PWM comparator 114, a timer capacitor 116, the first terminal P1, a second terminal P2 to which the Hi/Lo switching signal S2 is input, a third terminal P3 to which the output voltage Vo is applied, a fourth terminal P4 to which the voltage of one end of the current detection resistor Rd is applied, and a fifth terminal P5 to which the voltage of the other end of the current detection resistor Rd is applied.

[0045] The state detection circuit 102 detects an electrical state of the discharge lamp 226. The state detection circuit 102 is connected to the third terminal P3, and monitors the output voltage Vo. The state detection circuit 102 is also connected to the fourth terminal P4 and the fifth terminal P5, and measures the voltage drop Vd occurring in the current detection resistor Rd to arithmetically calculate the lamp current IL. The state detection circuit 102 inputs a power signal S3 having a voltage in correspondence to the power supplied to the discharge lamp 226 to an inverted input terminal of the error amplifier 110 via the adjustment circuit 106.

[0046] The error amplifier 110 amplifies an error between the voltage of the power signal S3 and a reference voltage Vref generated by the reference voltage source 108, and generates an error signal S4 having a voltage in correspondence to the amplified error. The value of the reference voltage Vref is set on the basis of desired target power. The error amplifier 110 inputs the error signal S4 to a non-inverted input terminal of the PWM comparator 114.

[0047] The saw-tooth wave generation circuit 112 generates a periodic signal S5 having a triangular wave-like or saw-tooth wave-like periodic voltage of the drive frequency f 1, and inputs the generated periodic signal S5 to an inverted input terminal of the PWM comparator 114.

[0048] The PWM comparator 114 generates the control pulse signal S1 by comparing the voltage of the error signal S4 with the voltage of the periodic signal S5. The PWM comparator 114 supplies the control pulse signal S1 to the first terminal P1.

[0049] The timing circuit 104 is connected to the third terminal P3, and applies the output voltage Vo or a voltage in correspondence to the output voltage Vo to one end of the timer capacitor 116. The other end of the timer capacitor 116 is grounded.

[0050] When the power supply switch 8 is turned ON and the discharge lamp lighting circuit 100 is powered up, the output voltage Vo which has been substantially 0 increases. In response to this, the timer capacitor 116 is charged through the timing circuit 104 until a given charge voltage is reached. When the power supply switch 8 is turned OFF in a state where the timer capacitor 116 is fully charged, the output voltage Vo immediately falls down to 0 substantially. The timing circuit 104 has a resistor for determining a time constant of discharge of the timer capacitor 116, and the timer capacitor 116 is discharged according to the time constant. Herein, the time constant of the discharge is predetermined, and the resistance value of the resistor of the timing circuit 104 is determined such that the predetermined time constant is realized. Consequently, from the voltage (both-end voltage) of one end of the timer capacitor 116 after the power supply switch 8 is turned OFF and the supply of the power to the discharge lamp 226 is stopped, elapsed time after the power supply to the discharge lamp 226 is stopped can be measured.

[0051] The timing circuit 104 generates a signal in correspondence to the voltage of one end of the timer capacitor 116 or a signal in correspondence to the elapsed time obtained from the voltage, e.g., judgment of hot/cold of the discharge lamp 226.

[0052] Particularly, the timing circuit 104 generates a TC signal S6 having a voltage in correspondence to the voltage of one end of the timer capacitor 116, and supplies the generated TC signal S6 to the adjustment circuit 106. It is to be noted that, in order to perform an adjustment based on the elapsed time after the supply of the power to the discharge lamp 226 is stopped, the adjustment circuit 106 uses a change in the TC signal S6 from the power-up of the discharge lamp lighting circuit 100 instead of using the TC signal S6. That is, the adjustment circuit 106 uses the TC signal S6 in order to increase the power supplied to the discharge lamp 226 during the transient time period.

[0053] The state detection circuit 102 generates a lamp current signal S7, a first lamp voltage signal S8, and a second lamp voltage signal S9 in accordance with a given control line design, and inputs them to the adjustment circuit 106. The lamp current signal S7 is a signal having a voltage in correspondence to the lamp current IL, e.g. , a voltage in proportion to the lamp current IL. Both of the first lamp voltage signal S8 and the second lamp voltage signal S9 are signals each having a voltage in correspondence to the lamp voltage as the both-end voltage of the discharge lamp 226, and the first lamp voltage signal S8 is different from the second lamp voltage signal S9 in the manner of dependence on the lamp voltage.

[0054] The adjustment circuit 106 combines the lamp current signal S7, the first lamp voltage signal S8, and the second lamp voltage signal S9 to generate the power signal S3. The adjustment circuit 106 is connected to the second terminal P2, and switches among weights of the individual signals at the time of the combination on the basis of the Hi/Lo switching signal S2. The adjustment circuit 106 includes a switching circuit 118, a first resistance switching circuit 120, a second resistance switching circuit 122, a first resistor 124, a second resistor 126, and a third resistor 128.

[0055] To one end of the second resistor 126, the lamp current signal S7 is input, and the other end thereof is connected to the inverted input terminal of the error amplifier 110.

[0056] To one end of the first resistor 124, the TC signal S6 is input, and the other end thereof is connected to the inverted input terminal of the error amplifier 110.

[0057] The third resistor 128 is a variable resistor, and one end thereof is connected to the inverted input terminal of the error amplifier 110, while the other end thereof is grounded.

[0058] The first resistance switching circuit 120 is provided between a terminal for outputting the first lamp voltage signal S8 of the state detection circuit 102 and the inverted input terminal of the error amplifier 110, and is constituted so as to be able to switch the resistance value on the basis of a first switching signal S10. The first resistance switching circuit 120 has a fourth switching element 144, an eighth resistor 146, and a ninth resistor 148. To one end of the eighth resistor 146, the first lamp voltage signal S8 is input, and the other end thereof is connected to one end of the ninth resistor 148. To a connection node between the other end of the eighth resistor 146 and one end of the ninth resistor 148, a drain of the fourth switching element 144 as the N-channel MOSFET is connected. To a gate of the fourth switching element 144, the first switching signal S10 is input. Both of a source of the fourth switching element 144 and the other end of the ninth resistor 148 are connected to the inverted input terminal of the error amplifier 110.

[0059] The second resistance switching circuit 122 is provided between a terminal for outputting the second lamp voltage signal S9 of the state detection circuit 102 and the inverted input terminal of the error amplifier 110, and is configured to be able to switch the resistance value based on a second switching signal S11. The second resistance switching circuit 122 has a fifth switching element 150, a tenth resistor 152, and an eleventh resistor 154. One end of the tenth resistor 152 is connected to one end of the eleventh resistor 154, and the second lamp voltage signal S9 is input to a connection node therebetween. The other end of the tenth resistor 152 is connected to a drain of the fifth switching element 150 as the N-channel MOSFET. To a gate of the fifth switching element 150, the second switching signal S11 is input. A source of the fifth switching element 150 and the other end of the eleventh resistor 154 are connected to the inverted input terminal of the error amplifier 110.

[0060] The switching circuit 118 switches the resistance value of each of the first resistance switching circuit 120 and the second resistance switching circuit 122 from the resistance value for the low-beam state to the resistance value for the high-beam state when the rising edge appears in the Hi/Lo switching signal S2. The switching circuit 118 has a first capacitor 130, a fourth resistor 132, a second switching element 134, a fifth resistor 136, a sixth resistor 138, a seventh resistor 140, and a third switching element 142.

[0061] One end of the fourth resistor 132 and one end of the first capacitor 130 are connected to the second terminal P2. The other end of the first capacitor 130 is grounded. The other end of the fourth resistor 132 is connected to a base of the second switching element 134 as an npn-type bipolar transistor. An emitter of the second switching element 134 is grounded. A collector of the second switching element 134 is connected to one end of the fifth resistor 136 and one end of the sixth resistor 138. The voltage of the collector of the second switching element 134 is supplied to the gate of the fourth switching element 144 as the first switching signal S10. To the other end of the fifth resistor 136, a fixed power supply voltage Vcc is applied. The other end of the sixth resistor 138 is connected to a base of the third switching element 142 as the npn-type bipolar transistor. An emitter of the third switching element 142 is grounded. A collector of the third switching element 142 is connected to one end of the seventh resistor 140. To the other end of the seventh resistor 140, the fixed power supply voltage Vcc is applied. The voltage of the collector of the third switching element 142 is supplied to the gate of the fifth switching element 150 as the second switching signal S11.

[0062] When the Hi/Lo switching signal S2 is at high level, the first switching signal S10 is turned to low level, while the second switching signal S11 is turned to high level. Accordingly, the fourth switching element 144 is turned OFF, the fifth switching element 150 is turned ON, the resistance value of the first resistance switching circuit 120 becomes a series combined resistance value of the eighth resistor 146 and the ninth resistor 148, and the resistance value of the second resistance switching circuit 122 becomes a parallel combined resistance value of the tenth resistor 152 and the eleventh resistor 154.

[0063] When the Hi/Lo switching signal S2 is at low level, the first switching signal S10 is turned to high level, while the second switching signal S11 is turned to low level. Accordingly, the fourth switching element 144 is turned ON, the fifth switching element 150 is turned OFF, the resistance value of the first resistance switching circuit 120 becomes the resistance value of the eighth resistor 146, and the resistance value of the second resistance switching circuit 122 becomes the resistance value of the eleventh resistor 154.

[0064] The individual circuit constants of the adjustment circuit 106 are determined based on the following design concept.

(1) When the state of the headlamp unit 210 is switched from the low-beam state to the high-beam state at the time of steady lighting, the discharge lamp lighting circuit 100 is required to perform control of increasing the power supplied to the discharge lamp 226. More specifically, the discharge lamp lighting circuit 100 is required to perform control of increasing the power from 25 W to 35 W.

(2) The discharge lamp lighting circuit 100 is required to provide the same maximum input power during the transient time period in the high-beam state and in the low-beam state. More specifically, the discharge lamp lighting circuit 100 is required to set the design maximum value of the power supplied to the discharge lamp 226 to about 60 W in both of the states.

(3) Even when the state of the headlamp unit 210 is switched at any timing from the transient time period to the time of steady lighting, the discharge lamp lighting circuit 100 is required to realize stable power control, i.e., smoothly perform the switching of the power.

[0065] Design procedures for determining the individual circuit constants are as follows.

(A) Constants for a control line which realizes power control in correspondence to the high-beam state (the maximum value of power/power at the time of steady state = 60 W/35 W) are calculated. Constants for a control line which realizes power control in correspondence to the low-beam state (the maximum value of power/power at the time of steady state = 60 W/25 W) are calculated.

(B) Two types of the calculated constants are compared with each other and, when two types of the control lines are switched, the individual resistance values are adjusted such that the number of resistors each in which the switching of the resistance value is required is reduced as much as possible. Particularly, in circuits of the type of the adjustment circuit 106, when the ratios of the individual resistance values are the same, the characteristics thereof are the same. In addition, among elements in the adjustment circuit 106, the first resistor 124 is a principal element which determines power to be supplied to the discharge lamp 226 during the transient time period. Consequently, in consideration of the above-described (2), the resistance value of the first resistor 124 is set as a fixed value which does not depend on the Hi/Lo switching signal S2. Subsequently, for each of the high-beam state and the low-beam state, the respective resistance values of the first resistance switching circuit 120, the second resistance switching circuit 122, the second resistor 126, and the third resistor 128 are determined based on the fixed resistance value of the first resistor 124. At this point, the resistance values are determined such that the power of 35 W in the high-beam state at the time of steady lighting and the power of 25 W in the low-beam state thereat are supplied to the discharge lamp 226. In addition, in the present embodiment, commonality of the resistance value of the second resistor 126 and commonality of the resistance value of the third resistor 128 have been achieved in both of the states of the headlamp unit 210.

(C) The resistance value of the first resistance switching circuit 120 determined for the high-beam state and the resistance value of the first resistance switching circuit 120 determined for the low-beam state are switched using the switching element in accordance with the transition of the Hi/Lo switching signal S2. The same applies to the second resistance switching circuit 122.

[0066] The configuration of the discharge lamp lighting circuit 100 has been described thus far. Subsequently, the operation thereof will be described. FIG. 4 is a graph showing an illustrative time-varying change of a luminous flux LF of the discharge lamp 226 and lamp power WL supplied to the discharge lamp 226. In FIG. 4, the vertical axis indicates magnitudes of the luminous flux LF and the lamp power WL, while the horizontal axis indicates time. FIG. 4 corresponds to the case where the state of the headlamp unit 210 is fixed to one of the states.

[0067] When the power supply switch 8 is turned ON at time t 0, the breakdown of the discharge lamp 226 is caused due to the high voltage pulse generated by the starter circuit 20, and the discharge lamp 226 is lit. Thereafter, during a transient time period TP 1 until the luminous flux LF is stabilized, the lamp power WL larger than that during a steady lighting time period TP 2 is supplied to the discharge lamp 226 in order to realize a quick rise of the luminous flux. Particularly, during the transient time period TP 1, the lamp power WL reaches a design maximum value WM of the power supplied to the discharge lamp 226, i.e., 60 W in this case.

[0068] During the steady lighting time period TP 2 in which light of a stable luminous flux LF is outputted from the discharge lamp 226, the lamp power WL takes a value in accordance with the state of the headlamp unit 210. Particularly, the lamp power WL takes a value of 35 W when the headlamp unit 210 is in the high-beam state and, takes a value of 25 W when the headlamp unit 210 is in the low-beam state.

[0069] The discharge lamp lighting circuit 100 according to the present embodiment supplies power to the discharge lamp 226 used as the light source of the headlamp unit 210 having light distribution change means for switching between two states having different light distribution patterns. The discharge lamp lighting circuit 100 changes the power supplied to the discharge lamp 226 in accordance with switching of the state in the headlamp unit 210. Accordingly, the range of the type of the light distribution pattern which can be switched is widened. For example, it is possible to realize a significant change in light distribution pattern which can not be realized only by the light distribution change means of the headlamp unit 210.

[0070] Particularly, the discharge lamp lighting circuit 100 according to the present embodiment increases the power supplied to the discharge lamp 226 at the timing of the switching from the low-beam state to the high-beam state in the headlamp unit 210. Consequently, even when a lower-power and lower-luminous flux discharge lamp 226 is used, it is possible to supply the sufficient amount of the luminous flux in the high-beam state, and satisfy specifications required in the high-beam state.

[0071] In addition, the discharge lamp lighting circuit 100 according to the present embodiment is configured such that the design maximum values of the power supplied to the discharge lamp 226 in the high-beam state and in the low-beam state are equal to each other. Consequently, during the transient time period TP 1 in which the power supplied to the discharge lamp 226 reaches the design maximum value, the power supplied to the discharge lamp 226 in the high-beam state and that in the low-beam state become substantially equal to each other. Therefore, by determining the design maximum value common to both of the states in consideration of life, durability, and required luminous flux rise characteristics of the discharge lamp 226, it is possible to reduce an effect on the life of the discharge lamp 226 by the switching of the state.

[0072] Further, the discharge lamp lighting circuit 100 according to the present embodiment supplies the power of 25 W which is lower than 30 W to the discharge lamp 226 at the time of steady lighting in the low-beam state. The input power at the time of a stable state of a typical vehicle discharge lamp currently produced is about 35 W. When the discharge lamp is lit at 35 W, the specifications required in the high-beam state can be satisfied without changing the supplied power. Herein, when the luminous efficiency of the current vehicle discharge lamp is assumed to be about 100 lm/W, the luminous flux of about 3000 lm is required in the high-beam state. Consequently, when the power supplied to the discharge lamp 226 is not more than 30 W, there is a high possibility that the specifications required in the high-beam state can not be satisfied. To cope with this, the discharge lamp lighting circuit 100 according to the present embodiment increases the power to be supplied at the timing of the switching to the high-beam state so that even the discharge lamp having the input power at the time of the stable state of not more than 30 W can satisfy the specifications required in the high-beam state.

[0073] FIG. 5 is a waveform diagram showing a rising waveform of the luminous flux measured by using the discharge lamp lighting circuit 100. The horizontal axis of FIG. 5 indicates time, while the vertical axis thereof indicates the luminous flux. As the discharge lamp 226, a low power discharge lamp was used. A waveform 302 shows a rising waveform of the luminous flux when the state of the headlamp unit 210 is fixed to the high-beam state. A waveform 304 shows a rising waveform of the luminous flux when the high-beam state and the low-beam state are switched at time intervals of 1 second. A waveform 306 shows a rising waveform of the luminous flux when the state of the headlamp unit 210 is fixed to the low-beam state. The power supply switch 8 was turned ON at time t1.

[0074] From FIG. 5, a power fluctuation of about 5 W, or about 100 lm when converted into the luminous flux resulting from the switching of the state was found during the transient time period. During the steady lighting time period, it was confirmed that the switching between 25 W and 35 W was smoothly performed as in the design concept.

[0075] Thus, the description has been given of the configuration and the operation of the discharge lamp lighting circuit 100 according to the embodiment. It is to be understood by those skilled in the art that the embodiment is shown by way of example only, and various modifications can be made to combinations of the components and the processing procedures and such modifications also fall within the scope of the present invention.

[0076] As described above, in the discharge lamp lighting circuit 100 according to the embodiment, the power fluctuation on the order of several W is found when the state of the headlamp unit 210 is switched during the transient time period. Hereinbelow, the description will be given of an adjustment circuit 156 according to a modification in which a measure for suppressing the fluctuation is taken.

[0077] The adjustment circuit 156 according to the modification masks the Hi/Lo switching signal S2 during the transient time period. Consequently, during the transient time period, the power supplied to the discharge lamp 226 is not changed at the timing of the switching of the state of the headlamp unit 210.

[0078] In addition, the adjustment circuit 156 according to the modification determines whether it is during the transient time period or the steady lighting time period by comparing the voltage of the TC signal S6 with a given threshold voltage. The voltage of the TC signal S6 gradually increases from the start of the lighting of the discharge lamp 226. The adjustment circuit 156 determines that it is during the transient time period when the voltage of the TC signal S6 is lower than the threshold voltage, and determines it is during the steady lighting time period when the voltage of the TC signal S6 is higher.

[0079] In this case, by utilizing the voltage of the timer capacitor 116 for measuring elapsed time after the headlamp unit 210 is turned off in the determination of the transient time period, it becomes unnecessary to additionally provide a circuit or an element for the determination of the transient time period.

[0080] FIG. 6 is a circuit diagram showing a configuration of the adjustment circuit 156 according to the modification. The adjustment circuit 156 according to the modification has a configuration in which a masking circuit 162 is added to the adjustment circuit 106 according to the embodiment.

[0081] The masking circuit 162 masks the Hi/Lo switching signal S2 during the transient time period, and fixes the circuit constant of the adjustment circuit 156 to that for the low-beam state. The masking circuit 162 has a sixth switching element 164, a twelfth resistor 166, a thirteenth resistor 168, a fourteenth resistor 170, a seventh switching element 172, an eighth switching element 174, and a fifteenth resistor 176.

[0082] A collector of the sixth switching element 164 as the npn-type bipolar transistor is connected to the base of the second switching element 134. An emitter of the sixth switching element 164 is grounded. A base of the sixth switching element 164 is connected to a collector of the eighth switching element 174 as a pnp-type bipolar transistor. One end of the twelfth resistor 166 and one end of the thirteenth resistor 168 are connected to the other end of the seventh resistor 140. The other end of the thirteenth resistor 168 is connected to one end of the fourteenth resistor 170, and a connection node therebetween is connected to a base of the seventh switching element 172 as the pnp-type bipolar transistor. The other end of the fourteenth resistor 170 is grounded. The other end of the twelfth resistor 166 is connected to an emitter of the seventh switching element 172 and an emitter of the eighth switching element 174. A collector of the seventh switching element 172 is grounded. To one end of the fifteenth resistor 176, the TC signal S6 is input, and the other end thereof is connected to a base of the eighth switching element 174.

[0083] In a switching circuit 160 and the masking circuit 162 shown in FIG. 6, when the voltage of the TC signal S6 is lower than the threshold voltage determined by the resistance values of the thirteenth resistor 168 and the fourteenth resistor 170, the sixth switching element 164 is turned ON. As a result, the base of the second switching element 134 is fixed to low level regardless of the Hi/Lo switching signal S2. Subsequently, when the voltage of the TC signal S6 increases and exceeds the threshold voltage, switching control based on the above-mentioned Hi/Lo switching signal S2 is performed.

[0084] It is to be noted that the threshold voltage may be determined by experiment.

[0085] FIG. 7 is a waveform diagram showing a rising waveform of the luminous flux measured by using a discharge lamp lighting circuit including the adjustment circuit 156 according to the modification. The horizontal axis of FIG. 7 indicates time, while the vertical axis thereof indicates the luminous flux. As the discharge lamp 226, a low power discharge lamp was used. Measurement conditions of a waveform 308, a waveform 310, and a waveform 312 correspond to those of the waveform 302, the waveform 304, and the waveform 306 of FIG. 5. The power supply switch 8 was turned ON at time t2.

[0086] According to the present modification, as seen in FIG. 7, it is possible to suppress the fluctuation in the luminous flux resulting from the switching of the state of the headlamp unit 210 during the transient time period. In addition, similarly to the embodiment, the switching between 25 W and 35 W is stably and smoothly performed during the steady lighting time period as in the design concept.

[0087] Alternatively, in order to simplify the circuit while maintaining the above-described masking function, each of the first resistance switching circuit 120 and the second resistance switching circuit 122 may be replaced with one resistor, and a resistor which can be switched ON/OFF by the Hi/Lo switching signal S2 may be provided in parallel with the third resistor 128 instead. The masking circuit may mask the ON/OFF switching during the transient time period.

[0088] In the embodiment, the description has been given of the case where the discharge lamp 226 is driven by an alternating current voltage. However, the voltage for driving the discharge lamp is not limited thereto, and the technical concept according to the embodiment may be applied to a discharge lamp lighting circuit in which the discharge lamp 226 is driven by a direct current voltage. In this case, the configuration obtained by removing the inverter circuit 30 from the configuration of the embodiment may also be used. Alternatively, the technical concept according to the embodiment may be applied to what is called a double converter type discharge lamp lighting circuit.

[0089] In the embodiment, the description has been given of the case where the insulating type DC/DC converter is used. However, the DC/DC converter is not limited thereto, and a non-insulating type DC/DC converter may also be used.

[0090] In the embodiment, the description has been given by assuming that the discharge lamp 226 and the discharge lamp lighting circuit 100 are separate from each other. However, the arrangement thereof is not limited thereto, and the discharge lamp may also be incorporated in the discharge lamp lighting circuit.

[0091] In the embodiment, the description has been given of the case where the discharge lamp lighting circuit 100 supplies power to the discharge lamp 226. However, the lighting circuit is not limited thereto. The technical concept according to the embodiment can also be applied to a lighting circuit which supplies power to a semiconductor light source such as a Light Emitting Diode (LED) or the like.

Claims

1. A discharge lamp lighting circuit (100) for supplying power to a discharge lamp (226) used as a light source of a vehicle lighting device capable of switching between a first state and a second state by light distribution change means
   wherein a light distribution pattern of the second state is different from a light distribution pattern of the first state, and
   characterized in that the discharge lamp lighting circuit is configured so that the power supplied to the discharge lamp (226) is changed at a timing of switching from the first state to the second state.

2. The discharge lamp lighting circuit (100) of claim 1, configured so that a reference value of the power supplied to the discharge lamp (226) in the first state and a reference value thereof in the second state are equal to each other.

3. The discharge lamp lighting circuit (100) of claim 1 or 2, configured so that, during a certain time period after a start of supplying the power to the discharge lamp (226) , the power supplied to the discharge lamp (226) does not change when switching from the first state to the second state.

4. The discharge lamp lighting circuit (100) of claim 3, comprising:

   a timer capacitor (116) for measuring elapsed time after performing control for stopping the supply of the power to the discharge lamp (226), wherein the discharge lamp lighting circuit (100) is configured so as to determine the certain time period based on a voltage of the timer capacitor (116).

5. The discharge lamp lighting circuit (100) of any one of claims 1 to 4,
   configured so that the power supplied to the discharge lamp (226) at the time of the switching from the first state to the second state is increased, and so that power lower than 30 watts is supplied to the discharge lamp (226) at a time of steady lighting in which light of a stable luminous flux is outputted from the discharge lamp (226) in the first state.

6. A method for supplying power from a discharge lighting circuit (100) to a discharge lamp (226) used as a light source of a vehicle lighting device capable of switching between a first state and a second state by light distribution means, wherein a light distribution pattern of the second state is different from a light distribution pattern of the first state, and
   wherein the power supplied to the discharge lamp is charged at a timing of switching from the first state to the second state.

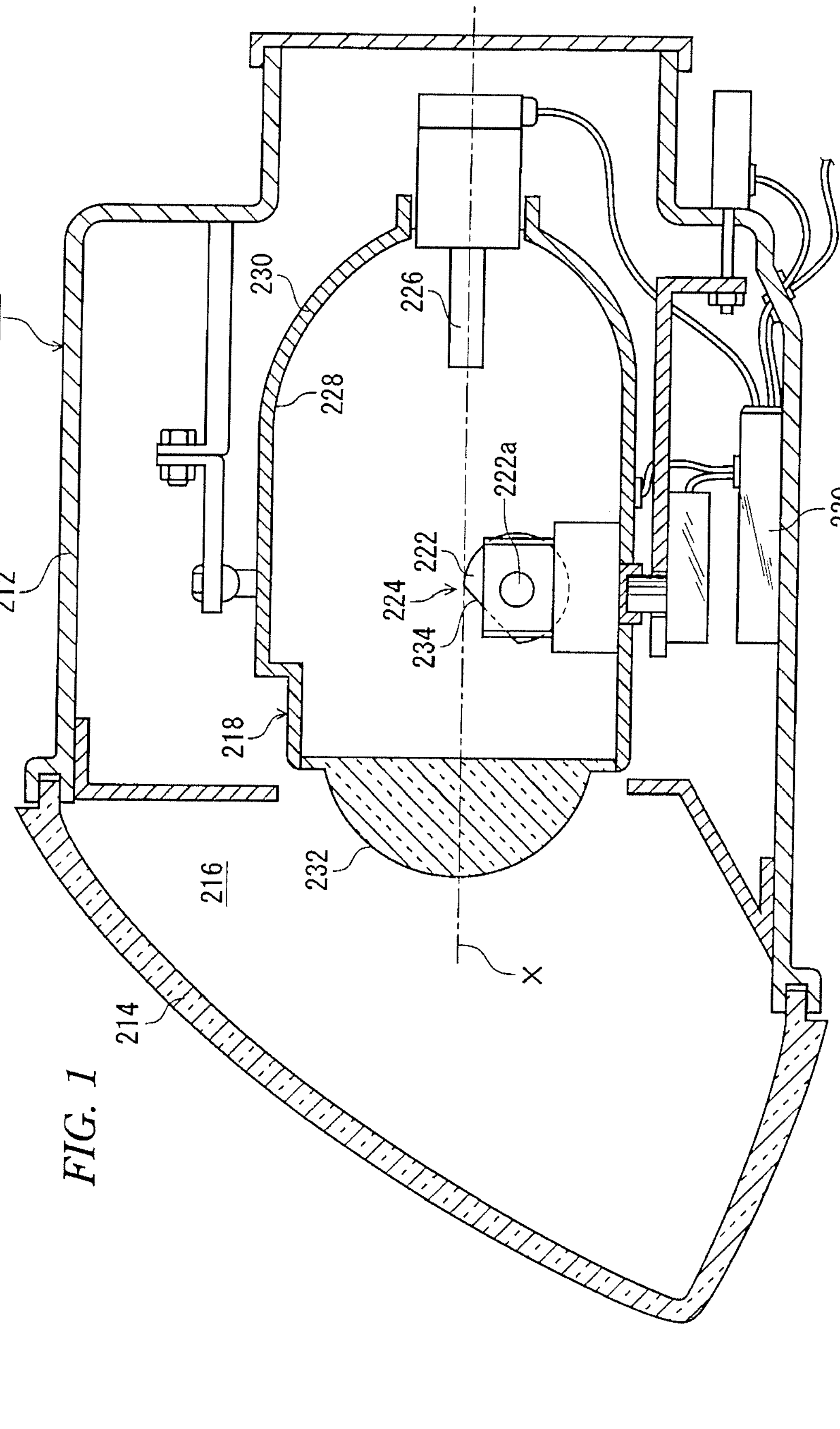
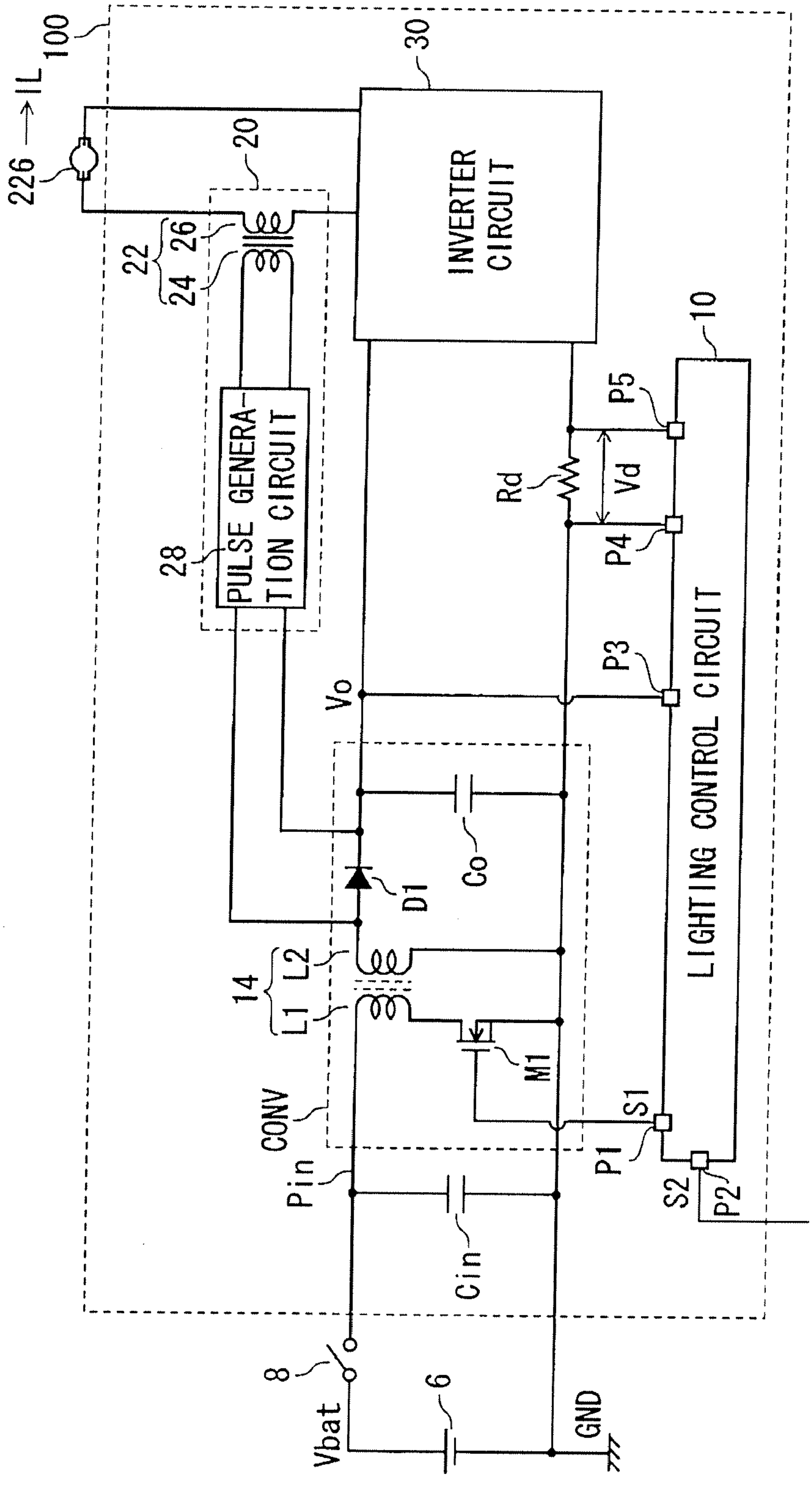


FIG. 1

FIG. 2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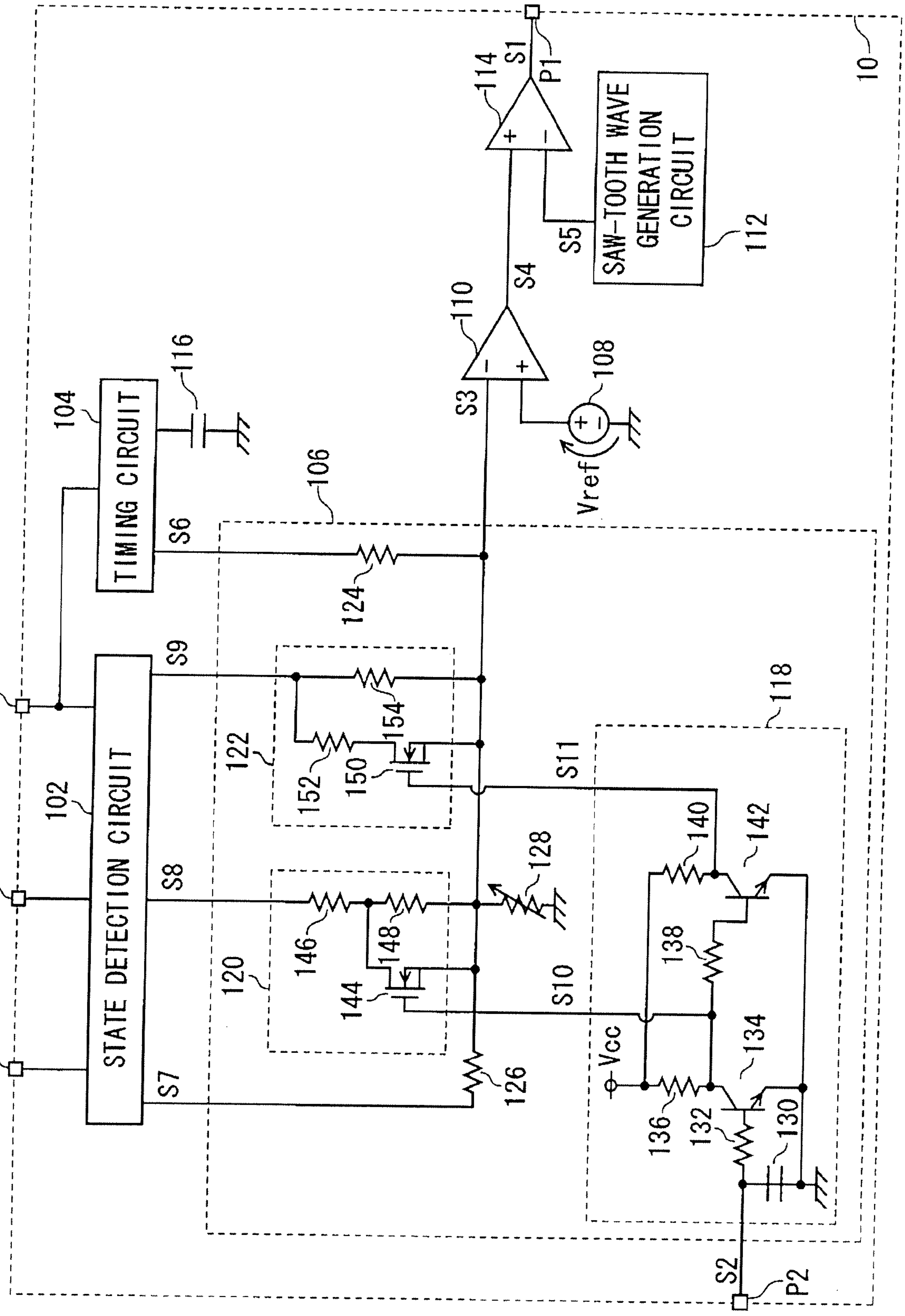
30
IL
226
20
22
24
26
INVERTER CIRCUIT
10
PULSE GENERATION CIRCUIT
28
P5
Rd
Vd
P4
P3
Vo
LIGHTING CONTROL CIRCUIT
Co
D1
14
L1
L2
M1
CONV
S1
P1
S2
P2
Pin
Cin
8
6
Vbat
GND

FIG. 3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TIMING CIRCUIT
SAW-TOOTH WAVE GENERATION CIRCUIT
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P2
P3
P4
P5
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
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FIG. 4

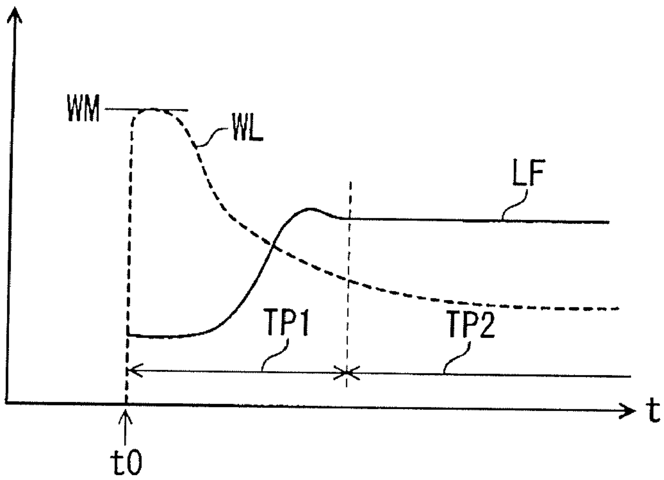


FIG. 5

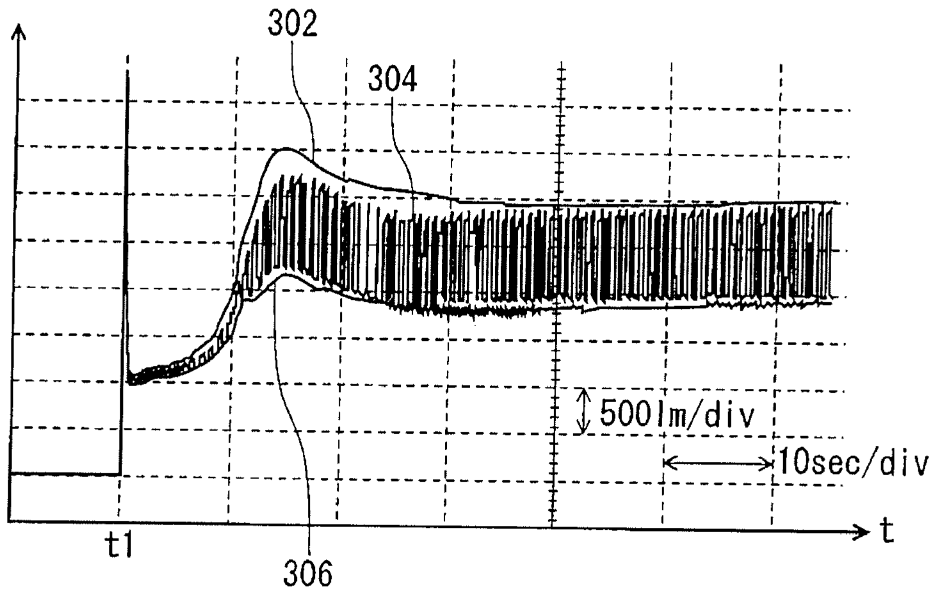
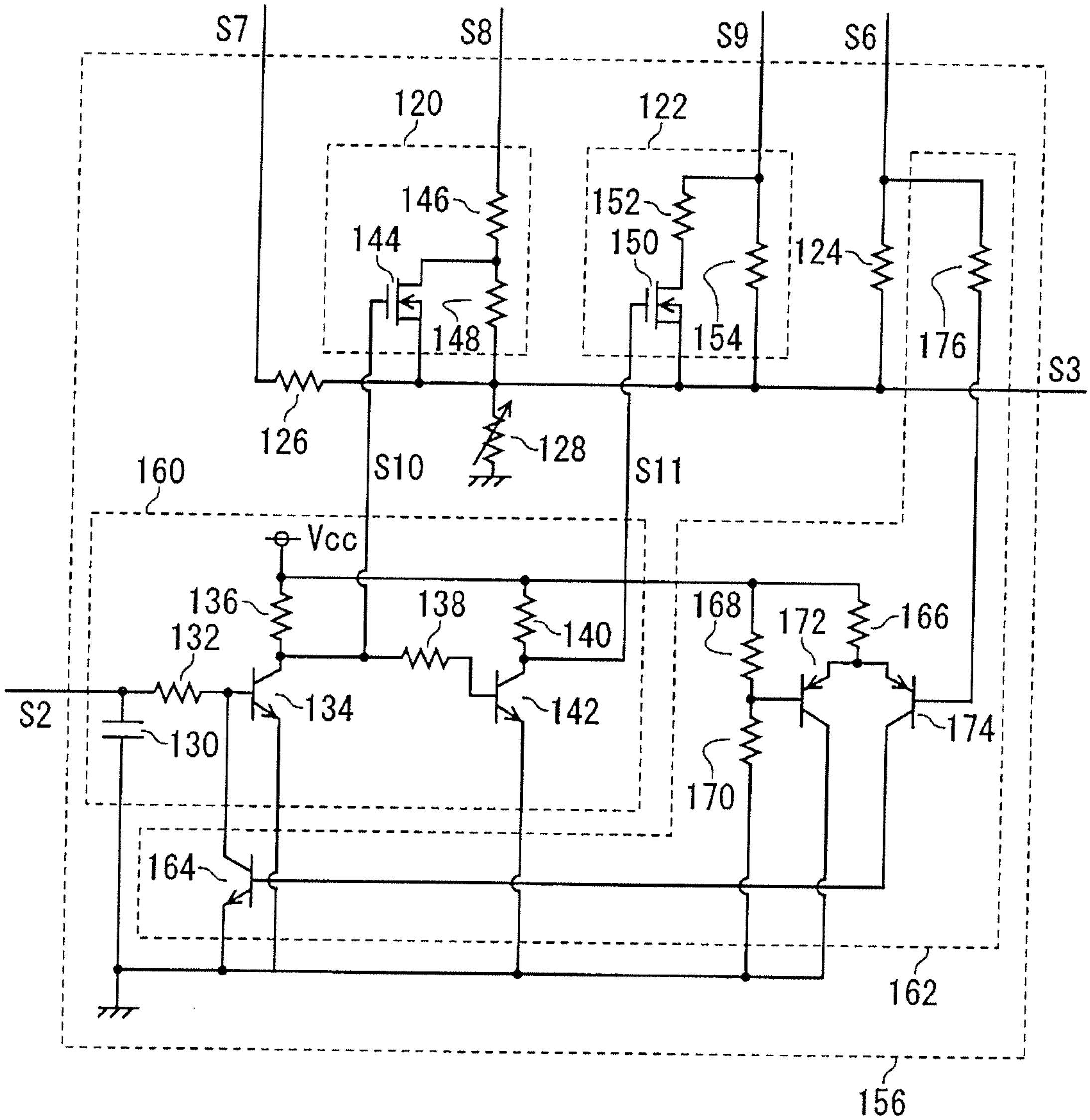


FIG. 6


S7
S8
S9
S6
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144
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S11
160
Vcc
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138
168
172
166
132
140
S2
134
142
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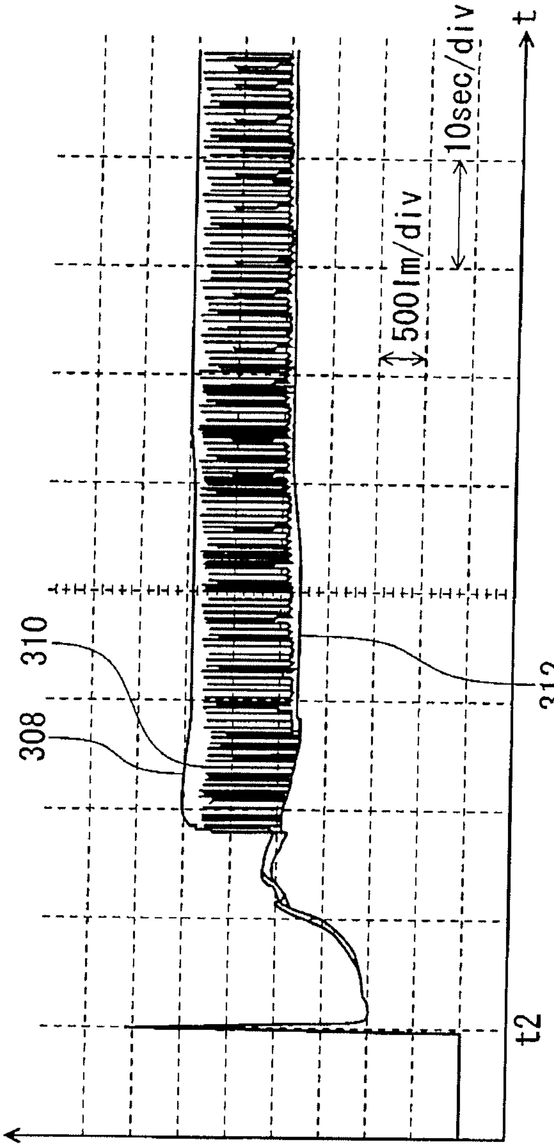
162
156

FIG. 7



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Application Number
EP 11 17 7472

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	29 December 2011	Hernandez Serna, J

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2

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Application Number
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