(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 449 224 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **91104798.3**

(51) Int. Cl.[5]: **H05B 41/29**, H05B 41/26

(22) Date of filing: **26.03.91**

(30) Priority: **29.03.90 JP 81645/90**

(43) Date of publication of application:
02.10.91 Bulletin 91/40

(84) Designated Contracting States:
DE GB

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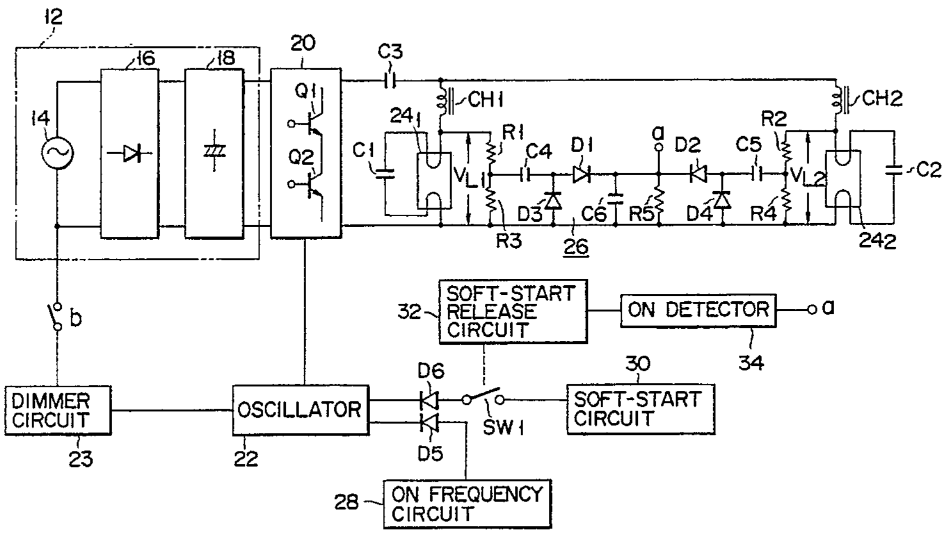
(54) Apparatus for operating discharge lamp.

(57) In an apparatus for operating discharge lamp of this invention, a DC output frequency supplied from a DC power source (12) can be varied by a high-frequency generator (20) and is supplied to a discharge lamp (24_1, 24_2). The ON state of the discharge lamp (24_1, 24_2) is detected by an ON detector (34). The output frequency of the high-frequency generator (20) is controlled such that a soft-start circuit (30) generates an output lower than that for normal ON operation of the discharge lamp (24_1, 24_2) during a start operation. At the same time, the output frequency of the high-frequency generator (20) is varied down to a level for the normal ON operation. When the ON detector (34) detects the ON operation of the discharge lamp (24_1, 24_2) the output frequency of the high-frequency generator (20) is switched to a level for the normal ON operation by a soft-start release circuit (32).



F I G. 1

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The present invention relates to an apparatus for operating discharge lamp and, more specifically, to a an apparatus for operating discharge lamp for turning on a discharge lamp such as a fluorescent lamp by a high-frequency output.

Recently, an electronic lighting apparatus has been used for turning on a discharge lamp, such as a fluorescent lamp, by a high-frequency output generated by a high-frequency generator. A high-frequency generator capable of varying its output frequency is used as a lighting apparatus. When a high-frequency generator of this type is used, a relationship between its output voltage and frequency is as follows. At a start operation, the output frequency of the high-frequency generator is set to be higher, e.g., 69 kHz, than that, e.g., 42 kHz, used for normal ON operation, so that the output voltage to the discharge lamp is lowered. Namely, so-called soft start is performed. A discharge lamp lighting apparatus having this characteristic has been proposed to prolong the service life of the discharge lamp.

When soft start is performed, the output frequency to the discharge lamp is controlled to vary toward the frequency for the normal ON operation. Therefore, even after the discharge lamp is turned on, the output frequency gradually changes in accordance with a time constant. This delays rising of the output voltage and it takes several seconds before a desired brightness is achieved, resulting in discomfort to the user.

It is, therefore, an object of the present invention to provide an apparatus for operating discharge lamp in which, at a start operation, it is detected that a discharge lamp is turned on and soft start is stopped, so that the brightness of the lamp can be instantaneously changed to a desired level.

According to an aspect of the present invention, there is provided an apparatus for operating discharge lamp comprising: a discharge lamp; direct-current power source means for supplying a direct current to the discharge lamp; high-frequency generating means capable of varying a direct-current output frequency from the direct-current power source means; soft-start circuit means for controlling, upon a start operation, the output frequency of the high-frequency generating means to be lower than that for a normal ON operation of the discharge lamp and to be changed to a level for the normal ON operation; ON detecting means for detecting that the discharge lamp is ON; and soft-start release means for switching the output frequency of the high-frequency generating means to that for the normal ON operation when the ON detecting means performs ON detection.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram of an apparatus for operating discharge lamp according to an embodiment of the present invention;

Fig. 2 is a graph showing a change in frequency of the apparatus for operating discharge lamp as a function of time;

Fig. 3 is a graph showing a relationship between an output voltage and a frequency of the apparatus for operating discharge lamp; and

Fig. 4 shows the detailed circuit configuration of the apparatus for operating discharge lamp shown in Fig. 1.

The preferred embodiment of the present invention will be described with reference to the accompanying drawings.

First, referring to Fig. 1, a DC power source 12 comprises a commercial AC power source 14, a rectifier 16 for rectifying the power from the power source 14, and a smoothing circuit 18 for smoothing the output from the rectifier 16 to obtain a DC output. The DC power source 12 is connected to an inverter 20 as a high-frequency generator. A high-frequency output is generated in accordance with an oscillated frequency output from an oscillator 22 connected to the inverter 20. A dimmer circuit 23 is connected between the DC power source 12 and the oscillator 22, and a switch b is inserted between the DC power source 12 and the dimmer circuit 23. The dimmer circuit 23, which operates on the voltage supplied from the DC power source 12, adjusts the amount of light by varying the output frequency of the oscillator 22. The inverter 20 can be, e.g., a half bridge inverter comprising a pair of transistors Q1 and Q2, as shown in Fig. 1.

Discharge lamps 24_1 and 24_2, e.g., fluorescent lamps, respectively, have capacitors C1 and C2. A high-frequency output is supplied from the inverter 20 to both electrodes of the discharge lamp 24_1 through a capacitor C3 and a choke coil CH1, and to both electrodes of the discharge lamp 24_2 through the capacitor C3 and a choke coil CH2. Terminal voltages V_{L1} and V_{L2} of the discharge lamps 24_1 and 24_2, respectively, are detected by a voltage detector 26 comprising resistors R1, R2, R3, R4, and R5, capacitors C4, C5, and C6, diodes D1, D2, D3, and D4, and the like, as shown in Fig. 1.

The terminal voltages V_{L1} and V_{L2} of the discharge lamps 24_1 and 24_2, respectively, are high when the corresponding discharge lamps are not ON, and are low when the corresponding discharge lamps are ON. Even when the discharge lamps are ON, if the service life of the discharge lamps 24_1 and 24_2 is running short after long-time use, the terminal voltages V_{L1} and V_{L2} are low.

Upon start operation of the discharge lamps 24_1 and 24_2, the output frequency from the inverter 20 to be supplied to the discharge lamps 24_1 and 24_2 is set higher than that for normal ON operation, and an output voltage applied to the discharge lamps 24_1 and 24_2 is set low. In other words, so-called soft start is performed. More specifically, the relationship between the frequency and the output voltage is as shown in Fig. 2. In a low-frequency band with a resonance frequency f_0 at its center, as the frequency is increased, the output voltage is increased. Contrary to this, in a high-frequency band, as the frequency is increased, the output voltage is decreased. Thus, using this relationship, during soft start operation, as previously described, an output voltage f_s is set at 69 kHz, which is higher than a frequency f_a of 42 kHz for the normal ON operation, and the output voltage applied to the discharge lamps 24_1 and 24_2 is set low.

The oscillator 22 is connected to an ON frequency circuit 28 through a diode D5, and to a soft-start circuit 30 through a diode D6 and a switch SW1. Each of the ON frequency circuit 28 and the soft-start circuit 30 supplies an oscillation control signal to the oscillator 22 so that a frequency having the above relationship with the output voltage is output from the inverter 20. More specifically, it is designed that the oscillation control signal from the soft-start circuit 30 causes a higher-frequency output than that from the ON frequency circuit 28 does. The oscillation control signal from the soft-start circuit 30 is applied to the oscillator 22 through the switch SW1.

A soft-start release circuit 32 is connected to an ON detector 34 and at the same time to the soft-start circuit 30 through the switch SW1. The ON detector 34 receives the terminal voltages V_{L1} and V_{L2} of the discharge lamps 24_1 and 24_2 from an output terminal a of the voltage detector 26 and detects from a voltage drop that the discharge lamps 24_1 and 24_2 are ON. The soft-start release circuit 32 is enabled when the ON detector 34 detects the ON state of the discharge lamps 24_1 and 24_2. As a result, the output from the soft-start circuit 30 is locked and is not input to the oscillator 22, thereby releasing the soft-start operation.

Referring to Fig. 4, the practical arrangement of the apparatus for operating discharge lamp of Fig. 1 will be described.

The circuit of Fig. 1 as the basic circuit configuration further comprises a starter 36, a safety circuit 38, a power ON-time reset circuit 40, a power OFF-time reset circuit 42, and the like.

A DC power source has a step-down insulated transformer Tr1. The primary winding of the transformer Tr1 is the commercial AC power source 14 side, and the secondary winding thereof is the rectifier 16 side.

The soft-start circuit 30 constitutes a kind of differentiator, and has a capacitor C7 and resistors R6 and R7 series-connected between a power source Vref and the ground voltage. When the power source Vref is applied to the soft-start circuit 30 to start the discharge lamps 24_1 and 24_2, the capacitor C7 is charged. Accordingly, a terminal voltage, corresponding to an upper terminal in the drawing, of the resistor R7 rises instantaneously, and simultaneously starts to drop in accordance with a predetermined time constant. This terminal voltage of the resistor R7 becomes the output voltage of the soft-start circuit 30. The output voltage is then divided by resistors R8, R9 and R10 through a diode D7, and is applied as an oscillation control signal to the base of an npn transistor Q3 having an emitter grounded through a resistor R11.

The oscillator 22 comprises, e.g., a voltage/frequency converter (to be referred to as a V/F converter hereinafter) and is connected to the collector of the transistor Q3. The V/F converter 22 oscillates in response to a frequency proportional to the voltage applied to the base of the transistor Q3, thereby driving the inverter 20 through an output transformer Tr2 or Tr3.

As a result, immediately after the start operation, the inverter 20 outputs a frequency sufficiently higher than that for the normal ON operation. However, as the output voltage from the soft-start circuit 30 drops, the output frequency of the inverter 20 is lowered. In this manner, the output voltage to be applied to the discharge lamps 24_1 and 24_2 is gradually increased, thereby executing soft start.

The starter 36 is connected between the DC power source 12 and the ON detector 34, and comprises a capacitor C8, transistors Q4 and Q5, and resistors R12, R13, R14, and R15. When the start operation is to be performed, the starter 36 sets the terminal voltage of the capacitor C7 at 0 V, thereby reliably enabling the soft-start circuit 30. Namely, upon start operation, the capacitor C8 is charged by a power source Vcc, so that the npn transistor Q5 is kept ON for a predetermined period of time to decrease its collector potential (serving as the collector potential of the transistor Q3).

The ON detector 34 has two npn transistors Q6 and Q7. The terminal voltages V_{L1} and V_{L2} of the discharge lamps 24_1 and 24_2 (not shown) are applied to the base of the transistor Q6. The collector of the transistor Q6 is connected to the power source Vcc, and the emitter thereof is grounded through resistors R16 and R17. The base of the other transistor Q7 is connected between the resistors R16 and R17, the collector thereof is connected to the power source Vcc through a resistor R18, and the emitter thereof is grounded.

During the ON operation of the discharge lamps 24_1 and 24_2 (Fig. 1), when their terminal voltages V_{L1} and V_{L2} are increased (when the service life of the discharge lamps are out), the safety circuit 38 increases the output frequency of the inverter 20 to lower the output voltage to the discharge lamps 24_1 and 24_2, thereby ensuring safety. More specifically, the safety circuit 38 receives the potential at the node of the emitter of the transistor Q6 and the resistor R16 of the ON detector 34. When the potential at the node of the resistor R16 and the emitter of the transistor Q6 is increased, a capacitor C9 is charged through a resistor R19. When the terminal voltage of the capacitor C9 exceeds the Zener voltage of a Zener diode ZD1, a transistor Q8 is turned on. As a result, a flip-flop FF having NOR gates 2 and 3 is enabled through a NOR gate NOR1, turning on a transistor Q9 through a diode D8. The transistor Q8 is connected to resistors R20 and R21.

The output voltage of the soft-start circuit 30, i.e., the potential at the node of the resistors R6 and R7 is kept high. As the terminal voltage of the capacitor C9 is increased, the collector potential of a transistor Q10 is increased through a diode D9. In this case, since the voltages V_{L1} and V_{L2} are increased to decrease the collector potential of the transistor Q7, a transistor Q11 (to be described later) of the soft-start release circuit 32 is OFF. As a result, the output voltage of the soft-start circuit 30 is applied to the base of the transistor Q3 through the diode D7 and the resistor R8. The voltage occurring at the node of the emitter of the transistor Q6 and the resistor R16 in accordance with the increase in voltages V_{L1} and V_{L2} is divided by resistors R22 and R23 and applied to the base of the transistor Q3 through a diode D10 and the resistor R8.

As a result, when the base potential of the transistor Q3 is increased, the oscillation frequency of the V/F converter 22 is increased to raise the output frequency of the inverter 20, thus lowering the output voltage to the discharge lamps 24_1 and 24_2. The discharge lamps 24_1 and 24_2 are protected in this manner.

The soft-start release circuit 32 has an npn transistor Q11 and resistors R24 and R25. The base of the transistor Q11 is connected to the collector of the transistor Q7 of the ON detector 34 through the resistor R24. The collector of the transistor Q11 is connected to the node of the resistors R6 and R7 that constitute the soft-start circuit 30, the emitter thereof is grounded, and the base thereof is grounded through the resistor R25.

When the discharge lamps 24_1 and 24_2 are not ON, the terminal voltages V_{L1} and V_{L2} thereof are high, as described above, and the transistors Q6 and Q7 are ON. The collector potentials of the transistors Q6 and Q7 are decreased to the ground potential. As a result, the transistor Q11 is OFF, and the output voltage of the soft-start circuit 30 is output unchanged, thus executing the soft-start operation described above.

When the discharge lamps 24_1 and 24_2 are turned on during the soft-start operation, their terminal voltages V_{L1} and V_{L2} are dropped, and the transistor Q7 is turned off. As a result, the collector potential of the transistor Q7 is increased to turn on the transistor Q11 of the soft-start release circuit 32. Then, the output of the soft-start circuit 30 is grounded, thus releasing the soft-start operation. A constant voltage element can be added to the soft-start release circuit 32 to set the threshold value.

The output of the ON frequency circuit 28 is applied to the base of the transistor Q3 through a diode D11 as the oscillation control signal. Thus, when the soft-start operation is stopped, the inverter 20 is controlled in accordance with the oscillation control signal input from the ON frequency circuit 28. The ON frequency circuit 28 has an arrangement as shown in Fig. 4. Namely, resistors R26, R27, R28, and R29, a diode D12, a Zener diode ZD2, and a capacitor C10 are connected between one input terminal of a NAND circuit NA1 and an input terminal b, and resistors R30, R31, and R32, and a transistor Q12 are connected to the output terminal of the NAND circuit NA1.

The ON frequency circuit 28 outputs a high-level voltage from its NAND circuit NA1 so that the inverter 20 outputs a predetermined frequency for the normal ON operation to the discharge lamps 24_1 and 24_2. Then, the transistor Q12 is turned off to supply a predetermined output (oscillation control signal) to the base of the transistor Q3. When a dimming signal is input to the input terminal b, the output voltage (oscillation control signal) to be applied to the transistor Q3 is varied through the diode D11. As a result, the oscillation frequency of the V/F converter 22 is changed to change the output frequency of the inverter 20, thus performing dimming control of the discharge lamps 24_1 and 24_2.

In the power-ON reset circuit 40, the transistor Q7 is ON for a predetermined period of time during the start operation, and the input terminal of a NAND circuit NA2 provided to the input side of the reset circuit 40 becomes low level. As a result, the output terminal of a NAND circuit NA3 provided to the output side of the reset circuit 40 becomes low level through a capacitor C11, resistors R33 and R34, and a diode D13. The pnp transistor Q9 connected to both terminals of the capacitor C7 provided to the soft-start circuit 30 is turned on through a diode D14 and resistors R35 and R36 to discharge the capacitor C7. As a result, the terminal voltage of the capacitor C7 becomes 0 V, and the soft-start circuit 30 is reliably reset in an enabled state.

When the power source is OFF, a predetermined pulse signal is input to a terminal c of the power OFF-time reset circuit 42. A transistor Q10 is kept OFF for predetermined period of time by this pulse signal through resistors R37 and R38, and the transistor Q9 is kept ON through a diode D15 during this period of time. As a result, the capacitor C7 is discharged to reset the soft-start circuit 30. Also, the capacitor C9 is discharged through the diode D9 to reset the safety circuit 38.

In this manner, when the service life of the discharge lamps 24_1 and 24_2 is out, their terminal voltages V_{L1} and V_{L2} are increased even if they are ON. Thus, the safety circuit 38 detects this state and increases the output frequency of the inverter 20 to protect the discharge lamps 24_1 and 24_2, thus lowering the voltage to be supplied to the discharge lamps 24_1 and 24_2. The values of the respective circuit elements must be set such that the safety circuit 38 does not operate during the start operation of the discharge lamps 24_1 and 24_2.

The overall operation will now be described. When the power source is turned on by the DC power source 12 to start the discharge lamps 24_1 and 24_2, the starter 36 and the power ON-time reset circuit 40 are operated, and the potential of the capacitor C7 of the soft-start circuit 30 are set at 0 V by the transistor Q9, thus reliably setting the enable state. When a predetermined period of time elapses after this, the transistor Q9 is turned off. Thus, the capacitor C7 is charged. The output voltage (the potential at the node of the resistors R6 and R7) of the soft-start circuit 30 rises instantaneously, and then continuously drops by a predetermined time constant. The output voltage is applied to the V/F converter 22 as the oscillation control signal through the diode D7 and the transistor Q3 to change the oscillation frequency of the V/F converter 22 and the output frequency of the inverter 20.

The initial value of the output voltage of the soft-start circuit 30 is set in such a manner to cause the inverter 20 to output a frequency sufficiently higher than that for the normal ON operation of the discharge lamps 24_1 and 24_2. As a result, as the output voltage of the soft-start circuit 30 continuously drops in accordance with the time constant, the output frequency of the inverter 20 is continuously increased. In this manner, the soft-start operation to continuously increase the output voltage to the discharge lamps 24_1 and 24_2 from a low value in accordance with the time constant is performed.

When the discharge lamps 24_1 and 24_2 are turned on during the soft-start operation, the ON detector 34 detects this and increases the collector potential of the transistor Q7 thereof. Thus, the transistor Q11 of the soft-start release circuit 32 is turned on to stop the operation of the soft-start circuit 30.

As a result of this stop operation, the voltage (soft-start oscillation control signal) applied to the base of the transistor Q3 is decreased at once down to the level of the output voltage (normal ON oscillation control signal) from the ON frequency circuit 28. More specifically, before the discharge lamps 24_1 and 24_2 are turned on, as the output voltage from the soft-start circuit 30 changes, the output frequency supplied to the discharge lamps 24_1 and 24_2 gradually decreases in accordance with the predetermined time constant. However, once the lamps 24_1 and 24_2 are turned on, the soft-start circuit 30 is stopped, and the output frequency to the lamps 24_1 and 24_2 decreases at once down to the level for the normal ON operation (the output voltage rises at once). As a result, the brightness of the lamps 24_1 and 24_2 rises instantaneously. The conventional problem of discomfort to the user before a desired brightness is achieved can thus be solved.

The inverter 20 can be of any type, such as a one-transistor type inverter, as far as the output frequency is variable.

The soft-start circuit 30 can be of a type that switches the output frequency in a stepwise manner.

The soft-start release circuit 32 can be of a type that forcibly switches the output frequency to the level of the normal ON operation regardless of the soft-start circuit 30.

Claims

1. An apparatus for operating discharge lamp having a discharge lamp, direct-current power source means for supplying a direct current to said discharge lamp, and high-frequency generating means, capable of varying a direct-current output frequency from said direct-current power source means, for turning on said discharge lamp by a high-frequency output from said high-frequency generating means, characterized by further comprising:

   soft-start circuit means (30) for controlling, upon a start operation, the output frequency of said high-frequency generating means (20) to be lower than that for a normal ON operation of said discharge lamp (24_1, 24_2) and to be changed to a level for the normal ON operation;

   ON detecting means (34) for detecting that said discharge lamp (24_1, 24_2) is ON; and

   soft-start release means (32) for switching the output frequency of said high-frequency generating means (20) to that for the normal

ON operation when said ON detecting means (34) performs ON detection.

2. An apparatus according to claim 1, characterized in that said ON detecting means (34) includes voltage detecting means (26) for detecting a terminal voltage of said discharge lamps (24_1, 24_2).

3. An apparatus according to claim 1, characterized by further comprising oscillator means (22) oscillated at a frequency in proportion to a predetermined voltage so as to drive said high-frequency generating means (20).

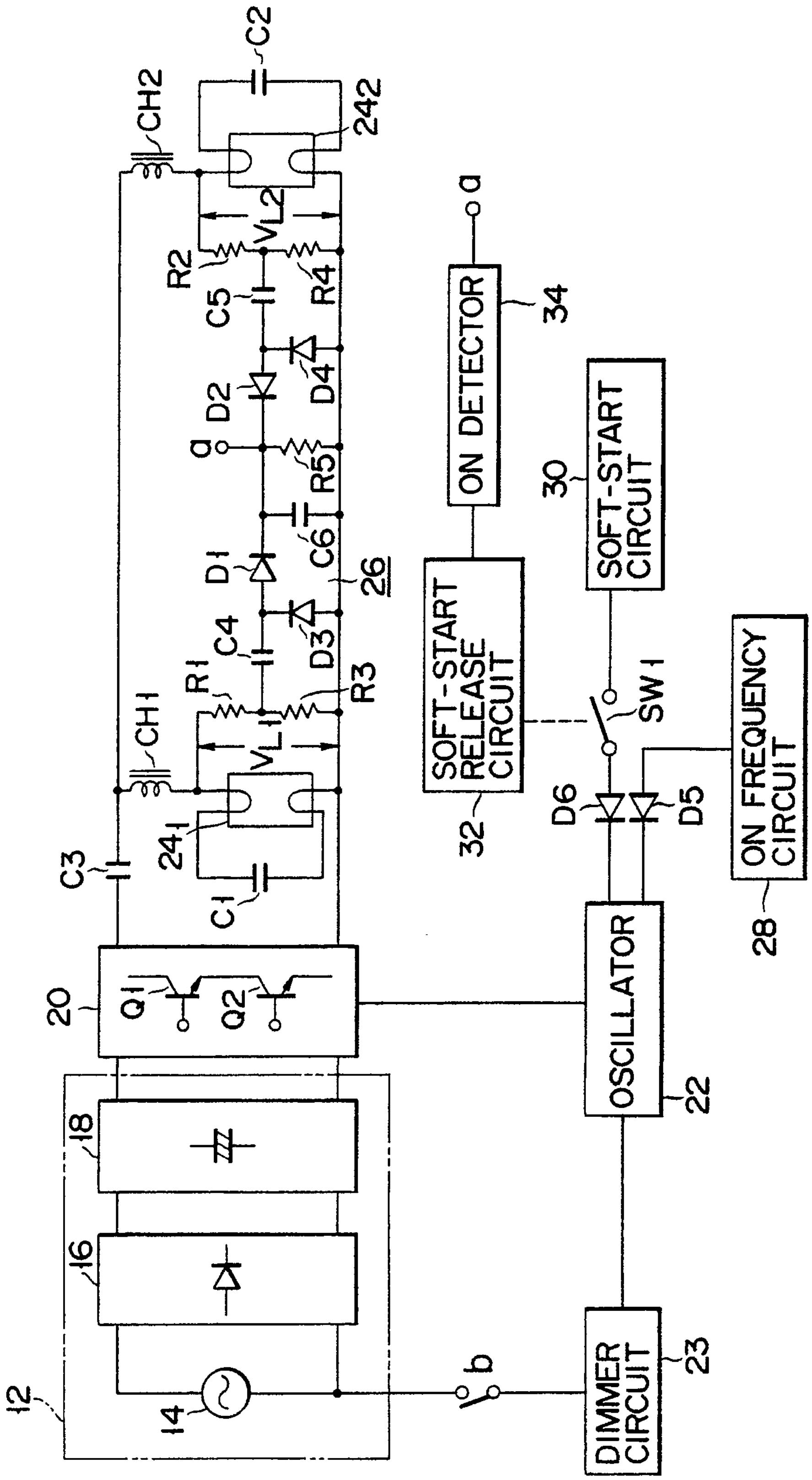
4. An apparatus according to claim 3, characterized by further comprising ON frequency circuit means (28) for supplying a frequency for turning on said discharge lamp (24_1, 24_2) to said oscillating means (22).

5. An apparatus according to claim 4, characterized by further comprising starter means (36), connected between said direct-current power source means (12) and said ON detecting means (34), for ensuring operation of said soft-start circuit means (30) upon start of said discharge lamp (24_1, 24_2).

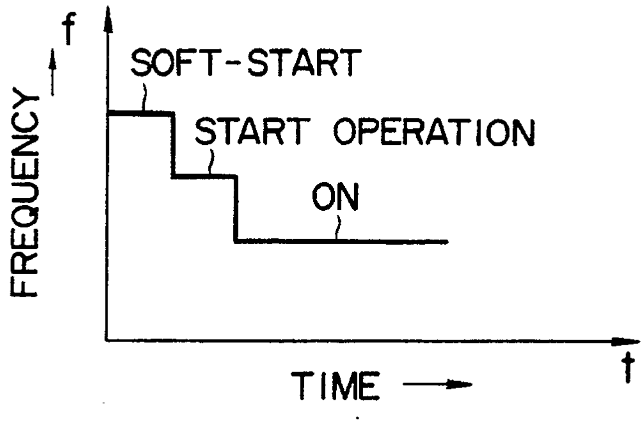
6. An apparatus according to claim 5, characterized by further comprising safety circuit means (38) for increasing, when said discharge lamp (24_1, 24_2) is ON and the terminal voltage thereof rises, the output frequency of said high-frequency generating means (20) to decrease the output voltage of said discharge lamp (24_1, 24_2).

7. An apparatus according to claim 6, characterized by further comprising power ON-time reset circuit means (40) for reliably resetting said soft-start circuit means (30) at an enabled state when said apparatus is turned on.

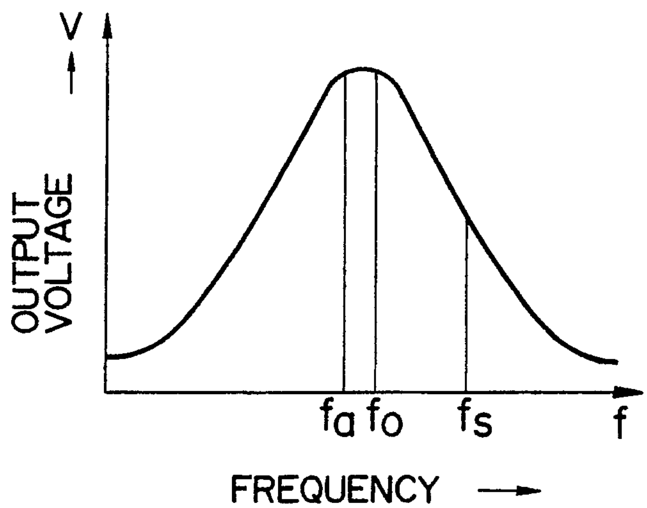
8. An apparatus according to claim 6, characterized by further comprising a power OFF-time reset circuit means (42) for resetting said soft-start circuit means (30) and said safety circuit means (38) when said apparatus is turned off.


12
14
16
18
20
Q1
Q2
C3
C1
241
CH1
VL1
R1
R3
C4
D3
D1
C6
26
a
R5
D2
D4
C5
R2
R4
VL2
CH2
242
C2
ON DETECTOR
34
a
SOFT-START RELEASE CIRCUIT
32
SOFT-START CIRCUIT
30
SW1
D6
D5
ON FREQUENCY CIRCUIT
28
OSCILLATOR
22
b
DIMMER CIRCUIT
23

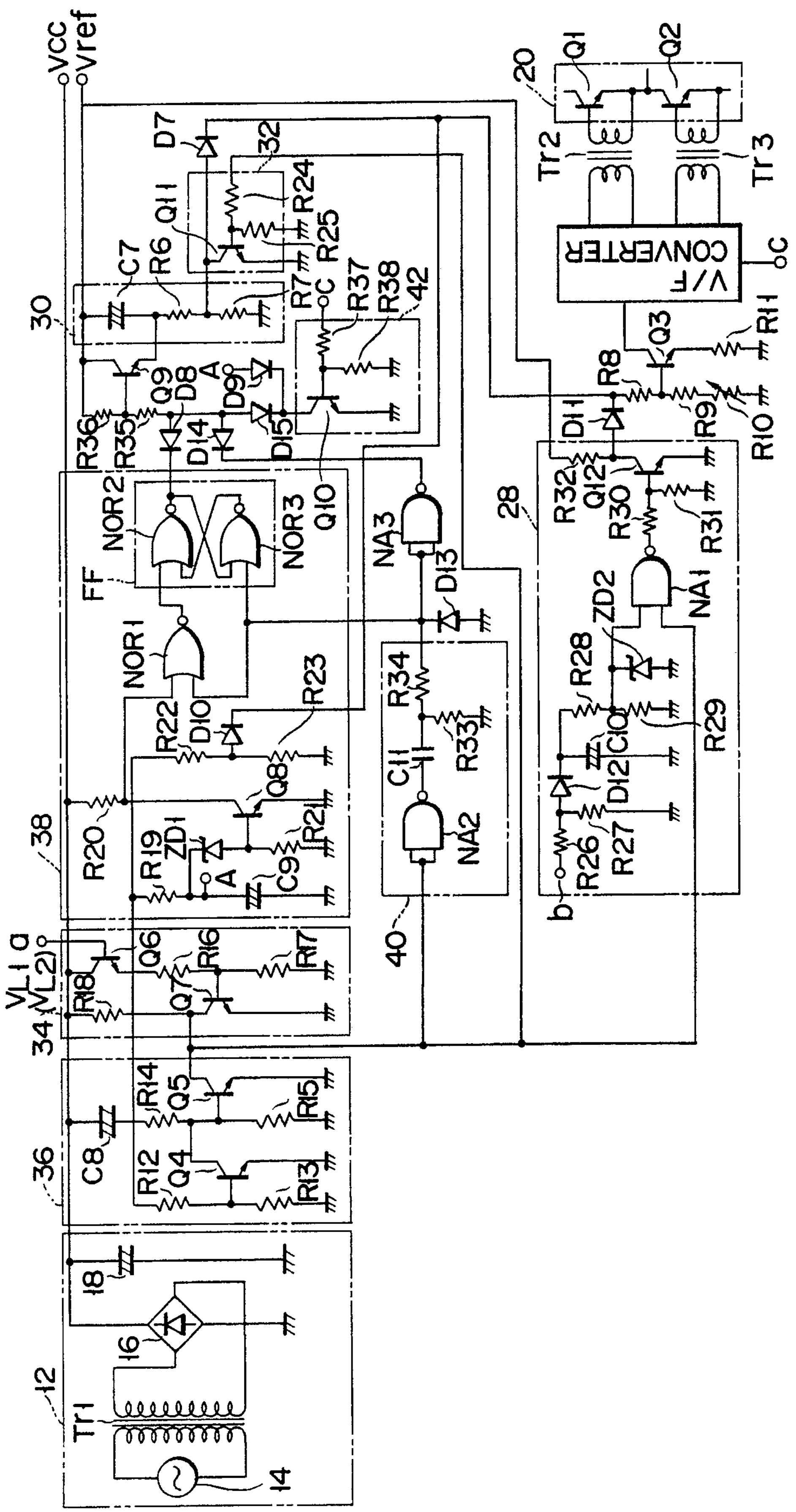
F I G. 1


f
SOFT-START
START OPERATION
ON
FREQUENCY
TIME
t

F I G. 2


V
OUTPUT VOLTAGE
fa fo fs f
FREQUENCY

F I G. 3


VCC
Vref
V/F CONVERTER
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Q1
Q2
Tr2
Tr3
Q3
R8
R9
R10
R11
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R32
Q12
R30
R31
NA1
ZD2
R28
R29
C10
D12
R26
R27
b
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C7
R6
R7
D7
32
R24
R25
Q11
R37
R38
42
A
Q9
D8
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D15
Q10
R36
R35
NOR2
NOR3
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R34
R33
C11
NA2
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R22
D10
R23
R20
R19
ZD1
Q8
R21
C9
38
VL1 a
(VL2)
34
Q6
Q7
R16
R17
R18
36
C8
R12
R13
R14
R15
Q4
Q5
12
Tr1
16
18
14

FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91104798.3

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	DE - A1 - 3 432 266 (F. KNOBEL) * Abstract; page 7, line 33 - page 12, line 5; fig. 1 * --	1-5	H 05 B 41/29 H 05 B 41/26
A	EP - A1 - 0 091 724 (WESTINGHOUSE) * Abstract; page 5, line 19 - page 8, line 36; fig. 1 * ----	1,3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H 05 B 41/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	28-06-1991	TSILIDIS

CATEGORY OF CITED DOCUMENTS

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