(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 July 2003 (17.07.2003)

PCT

(10) International Publication Number
WO 03/059018 A2

(51) International Patent Classification[7]: H05B 41/00

(21) International Application Number: PCT/IB03/00046

(22) International Filing Date: 10 January 2003 (10.01.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/043,586 10 January 2002 (10.01.2002) US

(71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors: ERHARDT, Robert; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). DEURLOO, Oscar; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). JANCZAK, Jerzy; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN ESVELD, Hendrik, A.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). COUWENBERG, Winston, D.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN DER VOORT, Ronald, H.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: BOSMA, Rudolphus, H., A.; Internationaal Octrooibureau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

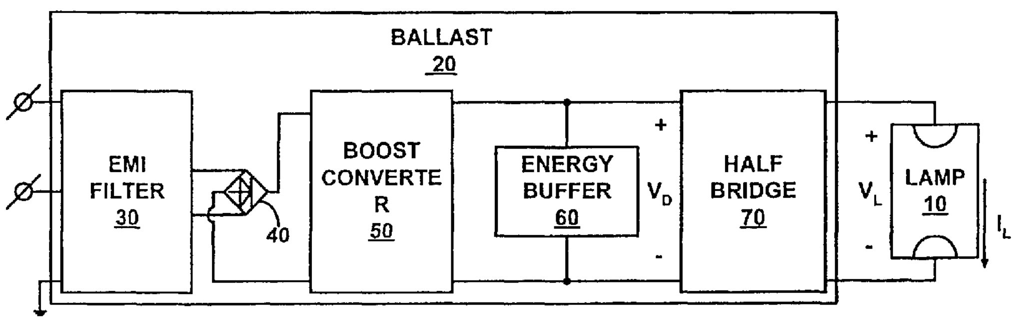
Declaration under Rule 4.17:
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for the following designation CN*

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 03/059018 A2

(54) Title: IMPROVED HIGH-FREQUENCY ELECTRONIC BALLAST



(57) Abstract: An improved high frequency ballast is disclosed. The high frequency ballast establishes a lamp current (I_L) for a gas discharge lamp (10) during a starting operation of the gas discharge lamp (10) wherein an operating ampere level of the lamp current (I_L) facilitates a substantial achievement by the gas discharge lamp (10) of a color specification associated with the gas discharge lamp (10). Thereafter, during a stable operation of the gas discharge lamp (10), the high frequency ballast applies a frequency modulation to an operating frequency of the lamp current (I_L) and/or an amplitude modulation of the lamp current (I_L).

Improved high-frequency electronic ballast

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to controlling an operation of various types of gas discharge lamps. The present invention specifically relates to an improvement in the operational performance of electronic ballast within a high frequency range of a gas discharge lamp.

2. Description of the Related Art

A high intensity discharge ("HID") gas discharge lamps as known in the art suffer from acoustic resonances when such lamps are operated within a high frequency HF operation between a few kHz and hundreds of kHz, depending on the type of lamp. However, the acoustic resonances significantly weaken within such gas discharge lamps whereby the acoustic resonance do not have negative affect on the performance of the gas discharge lamp when the gas discharge lamps are operated within a very high frequency operation that is above the highest acoustic resonance (e.g., 150 kHz for a 400W MH lamp). A consequence of operating the gas discharge lamp in the VHF operation is a generation of electro-magnetic interference. Additionally, when a gas discharge lamp is operated at HF lamp current, the electrode temperature modulation (i.e., difference in anode and cathode temperatures) will vanish. This results in a different electrode operating conditions, which could cause changes in the arc attachment on the electrode. Arc instabilities related with arc-electrode attachment have been found when 400W MH lamps are operated on high frequencies even up to as high as 500 kHz. Also, large coil differences between individual lamps are also found when lamps are operated on high frequencies.

Back-arcing of a gas discharge lamp involves an arc attachment of the arc on the back of the electrode coil of the lamp as opposed to an ideal arc attachment of the arc on the tip of the electrode. This can affect thermal balance of the end of the arc tube, which in turn can affect the vapor pressures. Consequently, the color properties of the lamp are affected. Currently, related prior art has failed to address back-arcing.

The present invention addresses the shortcomings of the prior art.

SUMMARY OF THE INVENTION

The present invention relates to an improved high frequency ballast. Various aspects of the present invention are novel, non-obvious, and provide various advantages. While the actual nature of the present invention covered herein can only be determined with reference to the claims appended hereto, certain features, which are characteristic of the embodiments disclosed herein, are described briefly as follows.

One form of the present invention is a first method of operating a half-bridge coupled to a gas discharge lamp. First, the half-bridge is operated to establish an operating frequency of a lamp current above all acoustic resonances within a high frequency operation range of the gas discharge lamp. Second, the half-bridge is operated to apply a frequency modulation to the operating frequency.

A second form of the present invention is a second method of operating a half-bridge coupled to a gas discharge lamp. First, the half-bridge is operated to establish an operating frequency of a lamp current. Second, the half-bridge is operated to apply an amplitude modulation to the lamp current in response to a reception by the half-bridge of a drive voltage having a waveform.

A third form of the present invention is a third method of operating a half-bridge coupled to a gas discharge lamp. First, the half-bridge is operated to establish an operating frequency of a lamp current above all acoustic resonances within a high frequency operation range of the gas discharge lamp. Second, the half-bridge is operated to apply a frequency modulation to the operating frequency. Finally, the half-bridge is operated to apply an amplitude modulation to the lamp current in response to a reception by the half-bridge of a drive voltage having a waveform.

A fourth form of the present invention is a fourth method of operating a half-bridge coupled to a gas discharge lamp. First, the half-bridge is operated to provide a lamp current to the lamp during a start-up operation of the gas discharge lamp. Second, the half-bridge is operated to establish the lamp current at an operating ampere level during an arc heating phase of the gas discharge lamp. The operating ampere level is equal to or greater than a minimum run-up ampere level to thereby impede any back-arcing within the gas discharge lamp whereby the gas discharge lamp substantially achieves a color specification for the gas discharge lamp.

The foregoing forms and other forms, features and advantages of the present invention will become further apparent from the following detailed description of the presently preferred embodiments, read in conjunction with the accompanying drawings. The detailed description and drawings are merely illustrative of the present invention rather than limiting, the scope of the present invention being defined by the appended claims and equivalents thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates one embodiment of a ballast in accordance with the present invention;

FIG. 2 illustrates one embodiment of a half-bridge in accordance with the present invention;

FIG. 3 illustrates an exemplary graph of a lamp voltage over time;

FIG. 4 illustrates an exemplary graph of a back-arcing risk vs. a lamp current;

FIG. 5 illustrates a first set of exemplary graphs of a drive voltage, a modulation voltage, and a lamp current;

FIG. 6 illustrates a second set of exemplary graphs of the drive voltage, the modulation voltage, and the lamp current;

FIG. 7 illustrates a third set of exemplary graphs of the drive voltage, the modulation voltage, and the lamp current;

FIG. 8 illustrates a fourth set of exemplary graphs of the drive voltage, the modulation voltage, and the lamp current; and

FIG. 9 illustrates a fifth set of exemplary graphs of the drive voltage, the modulation voltage, and the lamp current.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

FIG. 1 illustrates a ballast 20 of the present invention for providing a lamp current I_L to a conventional lamp 10. Ballast 20 comprises a electromagnetic interference filter 30, a MAINS rectifier 40, a boost converter 50, an energy buffer 60, and a half-bridge 70 coupled in a conventional arrangement whereby a drive voltage V_D is applied to half-bridge 70.

FIG. 2 illustrates half-bridge 70 including a micro-controller 71, a voltage controlled oscillator 72 ("VCO 72"), a half-bridge driver 73, a transistor T_1, a transistor T_2, a transformer TF, an inductor L, a capacitor C_1, a capacitor C_2, and an impedance component Z. Micro-controller 71 and a drain of transistor T_1 are coupled to a node N1 to receive drive voltage V_D. A source of transistor T_1, a drain of transistor T_2 and transformer TF are coupled to a node N2. Micro-controller 71, a source of transistor T_2 and impedance component Z are coupled to a node N3 whereby micro-controller 71 receives a drive current I_D. Micro-controller 71 is also coupled to transform TF to receive a feedback current I_F. Transformer TF, inductor L and capacitor C_1 are coupled in series. Capacitor C_1, capacitor C_2 and lamp 10 are coupled to a node N4 with capacitor C_2 and lamp 10 coupled in parallel between node N4 and a node N5.

VCO 72 conventionally establishes an operating frequency of lamp current I_L above all acoustic resonances within the high frequency range of operation. Micro-controller 71 comprises analog circuitry, digital circuitry, or a combination of analog circuitry and digital circuitry in generating a modulation voltage V_{FMS} in response to a reception of drive voltage V_D, a drive current I_D, and a feedback current I_F. In response to frequency modulation voltage V_{FMS}, VCO 72 applies a corresponding frequency modulation to the operating frequency of lamp current I_L. VCO 72 provides a control voltage V_C as an indication of the frequency modulation to the operating frequency of lamp current I_L. In response to control voltage V_C, half-bridge driver 73 operates transistor T_1 and transistor T_2 whereby lamp current I_L is provided to lamp 10.

Micro-controller 71 determines an input power P_{IN} to half bridge 70 by measuring drive voltage V_D and averaging drive current I_D. In one embodiment, input power P_{IN} is determined by multiplying both drive voltage V_D and the average drive current I_D. The lamp voltage V_L can be derived by subtracting any power losses P_{LOSS} by half bridge 70 of the computed input power P_{IN} and dividing this result by the lamp current I_L under the following equation [1]:

$$(P_{IN}-P_{LOSS})/I_L \qquad [1]$$

FIG. 3 illustrates the lamp voltage V_L over time. A starting operation of the gas discharge lamp 10 consists of a lag time phase, a breakdown (“BD”) phase, an electrode heating phase, and an arc tube heating phase. It is imperative during the arc tube heating phase to minimize, if not eliminate, any back-arcing within the gas discharge lamp 10 to thereby facilitate a substantial achievement by the gas discharge lamp of a color specification associated with the gas discharge lamp 10. As such, micro-controller 71 establishes an operating ampere level of the lamp current I_L that is equal to or greater than a run-up ampere level I_{RUN-UP} as shown in FIG. 4. In one embodiment, the run-up ampere level I_{RUN-UP} is 85%

of a maximum ampere level I_{MAX} for the lamp current I_L as established for the gas discharge lamp 10.

FIG. 5 illustrates one embodiment of drive voltage V_D and modulation voltage V_{FMS} having a frequency modulation Δf (e.g., 5 kHz) and a frequency sweep F_{sweep} (e.g., 200 Hz) in deriving lamp current I_L. The result is a stabilization of an arc (not shown) of lamp 10.

FIG. 6 illustrates a second embodiment of drive voltage V_D and modulation voltage V_{FMS} having a frequency modulation Δf (e.g., k5 Hz) and a frequency sweep F_{sweep} (e.g., 200 Hz) in deriving lamp current I_L.

FIG. 7 illustrates a third embodiment of drive voltage V_D having an amplitude modulation and a frequency (e.g., 120 Hz) and modulation voltage V_{FMS} in deriving lamp current I_L. Those having ordinary skill in the art will appreciate that the ballast 20 provides drive voltage V_D based upon a valley fill technique.

FIG. 8 illustrates a third embodiment of drive voltage V_D having an amplitude modulation and a frequency (e.g., 120 Hz) and modulation voltage V_{FMS} in deriving lamp current I_L. Those having ordinary skill in the art will appreciate that the ballast 20 provides drive voltage V_D based upon a follower boost technique.

FIG. 9 illustrates a fifth embodiment of drive voltage V_D having an amplitude modulation and a frequency (e.g., 120 Hz) and modulation voltage V_{FMS} having a frequency modulation Δf (e.g., k5 Hz) and a frequency sweep F_{sweep} (e.g., 200 Hz) in deriving lamp current I_L.

While the embodiments of the present invention disclosed herein are presently considered to be preferred, various changes and modifications can be made without departing from the spirit and scope of the present invention. The scope of the present invention is indicated in the appended claims, and all changes that come within the meaning and range of equivalents are intended to be embraced therein.

CLAIMS:

1. A method of operating a half-bridge (70) coupled to a gas discharge lamp (10), said method comprising:

operating the half-bridge (70) to establish an operating frequency of a lamp current (I_L) above all acoustic resonances within a high frequency operation range of the gas discharge lamp (10); and

operating the half-bridge (70) to apply a frequency modulation to the operating frequency.

2. A method of operating a half-bridge (70) coupled to a gas discharge lamp (10), said method comprising:

operating the half-bridge (70) to establish an operating frequency of a lamp current (I_L); and

operating the half-bridge (70) to apply an amplitude modulation to the lamp current (I_L) in response to a reception by the half-bridge (70) of a drive voltage having a waveform.

3. A method of operating a half-bridge (70) coupled to a gas discharge lamp (10), said method comprising:

operating the half-bridge (70) to establish an operating frequency of a lamp current (I_L) above all acoustic resonances within a high frequency operation range of the gas discharge lamp (10);

operating the half-bridge (70) to apply a frequency modulation to the operating frequency; and

operating the half-bridge (70) to apply an amplitude modulation to the lamp current (I_L) in response to a reception by the half-bridge (70) of a drive voltage (V_D) having a waveform.

4. A method of operating a half-bridge (70) coupled to a gas discharge lamp (10), said method comprising:

operating the half-bridge (70) to provide a lamp current (I_L) to the lamp (10) during a start-up operation of the gas discharge lamp (10); and

operating the half-bridge (70) to establish the lamp current (I_L) at an operating ampere level during an arc heating phase of the gas discharge lamp (10), the operating ampere level being equal to or greater than a minimum run-up ampere level to thereby impede any back-arcing within the gas discharge lamp (10) whereby the gas discharge lamp (10) substantially achieves a color specification for the gas discharge lamp (10).

5. The method of claim 4, further comprising:

operating the half-bridge (70) to establish an operating frequency of the lamp current (I_L) during a stable operation of the gas discharge lamp (10), the operating frequency being above all acoustic resonances within a high frequency operation range of the gas discharge lamp (10); and

operating the half-bridge (70) to apply a frequency modulation to the operating frequency.

6. The method of claim 4, further comprising:

operating the half-bridge (70) to establish an operating frequency of the lamp current (I_L); and

operating the half-bridge (70) to apply an amplitude modulation to the lamp current (I_L) in response to a reception by the half-bridge (70) of a drive voltage (V_D) having a waveform.

7. The method of claim 4, further comprising:

operating the half-bridge (70) to establish an operating frequency of the lamp current (I_L) during a stable operation of the gas discharge lamp (10), the operating frequency being above all acoustic resonances within a high frequency operation range of the gas discharge lamp (10);

operating the half-bridge (70) to apply a frequency modulation to the operating frequency; and

operating the half-bridge (70) to apply an amplitude modulation to the lamp current (I_L) in response to a reception by the half-bridge (70) of a drive voltage (V_D) having a waveform.

8. The method of claim 4, wherein the operating ampere level of the lamp current (I_L) during an arc heating phase of the gas discharge lamp (10) is at least 85% of the maximum ampere level for the lamp current (I_L).

9. A half-bridge (70) coupled to a gas discharge lamp (10), said half-bridge (70) comprising:

means for establishing an operating frequency of a lamp current (I_L) above all acoustic resonances within a high frequency operation range of the gas discharge lamp (10); and

means for applying a frequency modulation to the operating frequency.

10. A half-bridge (70) coupled to a gas discharge lamp (10), said half-bridge (70) comprising:

means for establishing an operating frequency of a lamp current (I_L); and

means for applying an amplitude modulation to the lamp current (I_L) in response to a reception by the half-bridge (70) of a drive voltage (V_D) having a waveform.

11. A half-bridge (70) coupled to a gas discharge lamp (10), said half-bridge (70) comprising:

means for establishing an operating frequency of a lamp current (I_L) above all acoustic resonances within a high frequency operation range of the gas discharge lamp (10);

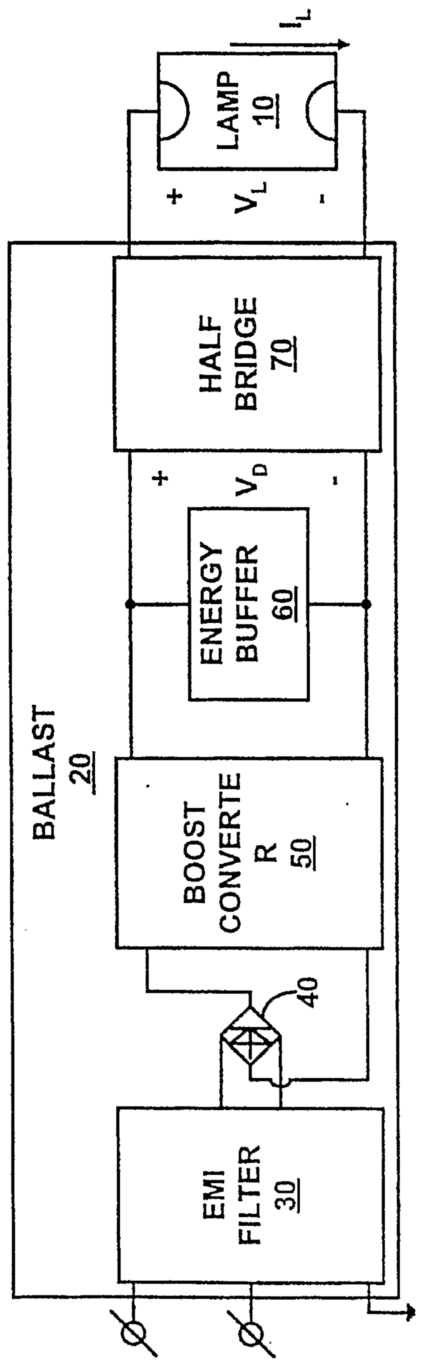
means for applying a frequency modulation to the operating frequency; and

means for applying an amplitude modulation to the lamp current (I_L) in response to a reception by the half-bridge (70) of a drive voltage (V_D) having a waveform.

12. A half-bridge (70) coupled to a gas discharge lamp (10), said half-bridge (70) comprising:

means for providing a lamp current (I_L) to the lamp (10) during a start-up operation of the gas discharge lamp (10); and

means for establishing the lamp current (I_L) at an operating ampere level during an arc heating phase of the gas discharge lamp (10), the operating ampere level being equal to or greater than a minimum run-up ampere level to thereby impede any back-arcing within the gas discharge lamp (10) whereby the gas discharge lamp (10) substantially achieves a color specification for the gas discharge lamp (10).



LAMP
10
I_L
+
V_L
-
HALF
BRIDGE
70
+
V_D
-
ENERGY
BUFFER
60
BALLAST
20
BOOST
CONVERTE
R
50
40
EMI
FILTER
30

FIG. 1

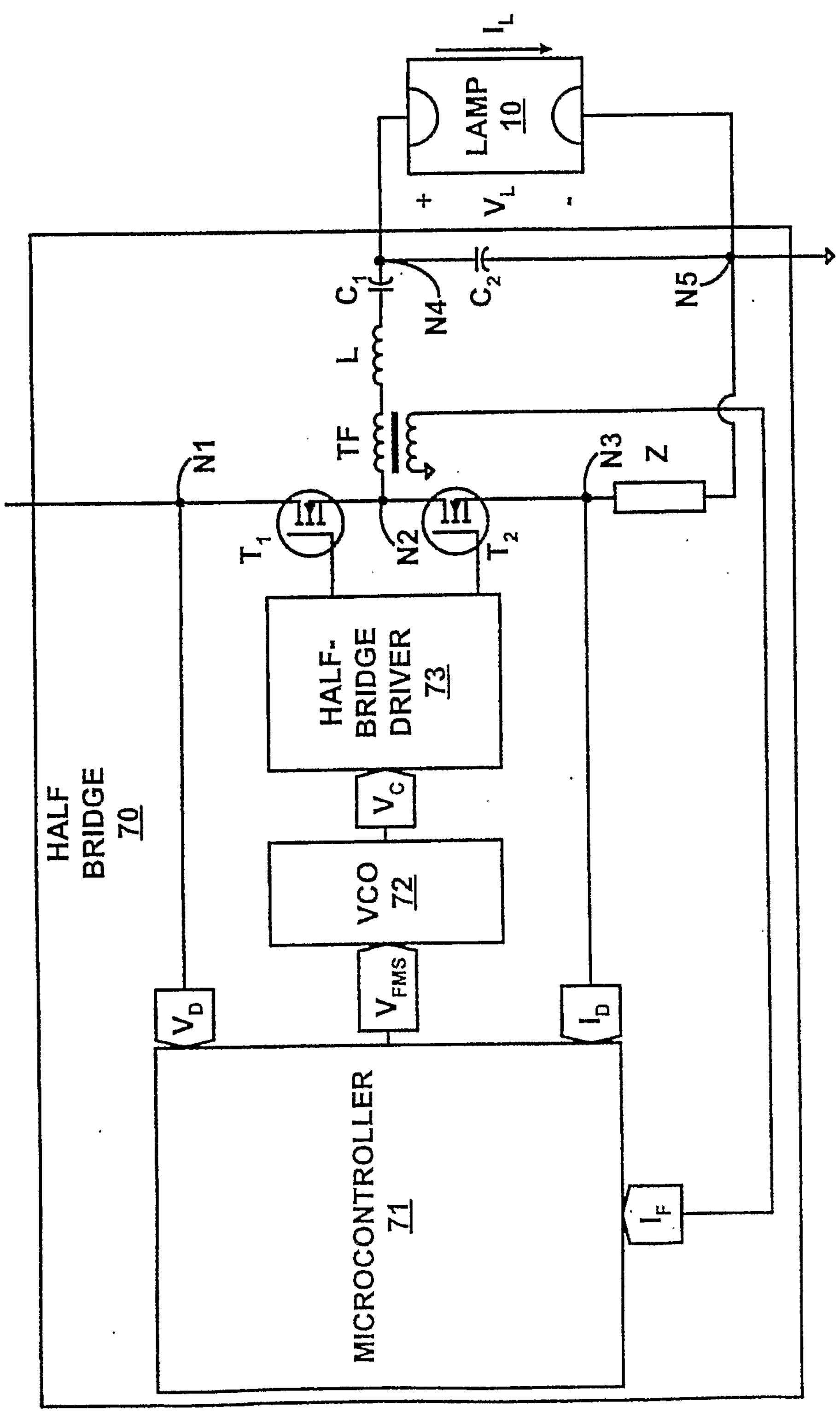

I_L
LAMP
10
+
V_L
-
C_1
C_2
L
TF
N1
N2
N3
N4
N5
T_1
T_2
Z
HALF-
BRIDGE
DRIVER
73
V_C
VCO
72
V_FMS
V_D
I_D
I_F
MICROCONTROLLER
71
HALF
BRIDGE
70

FIG. 2

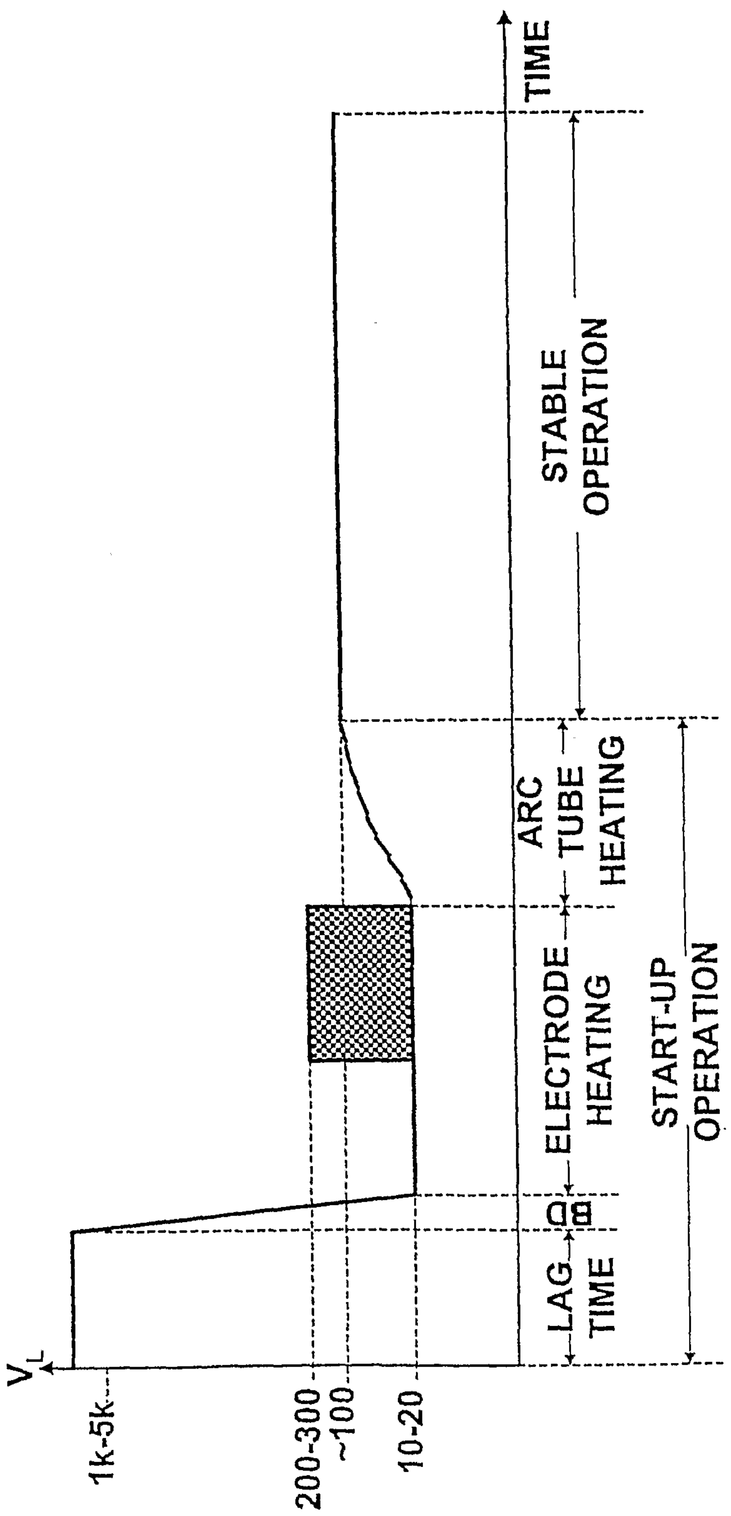

TIME
STABLE OPERATION
ARC TUBE HEATING
ELECTRODE HEATING
BD
LAG TIME
START-UP OPERATION
V_L
1k-5k
200-300
~100
10-20

FIG. 3

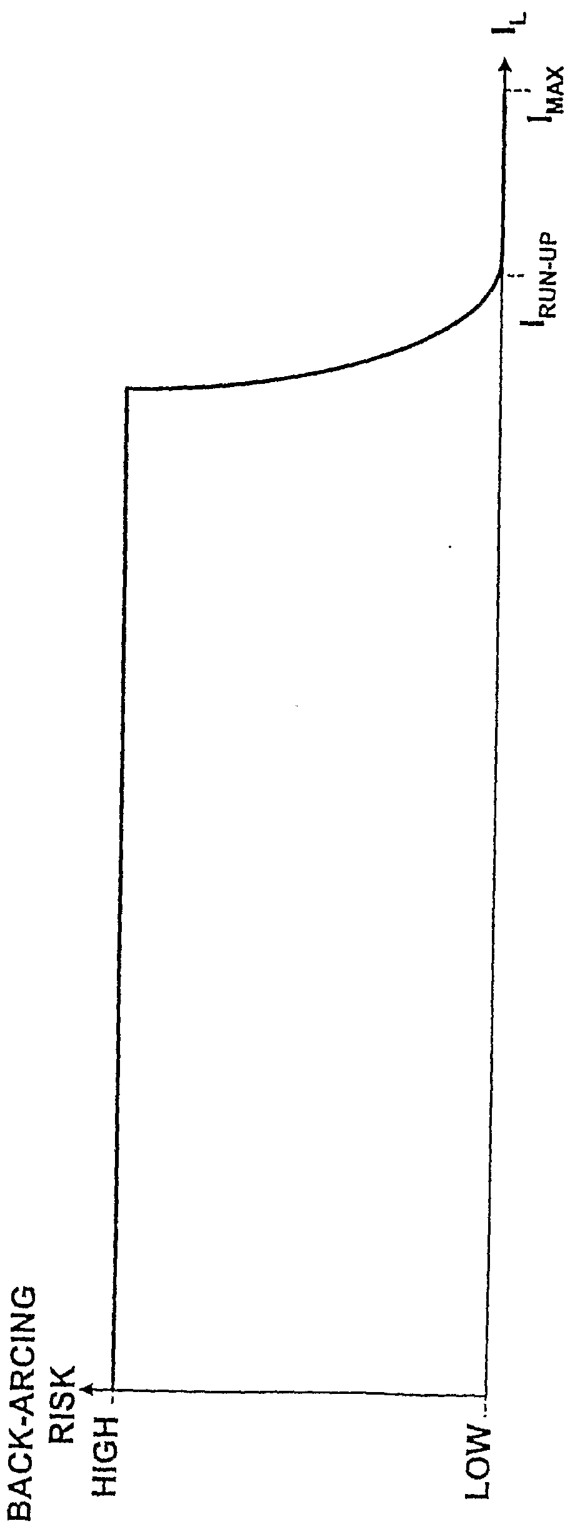


FIG. 4

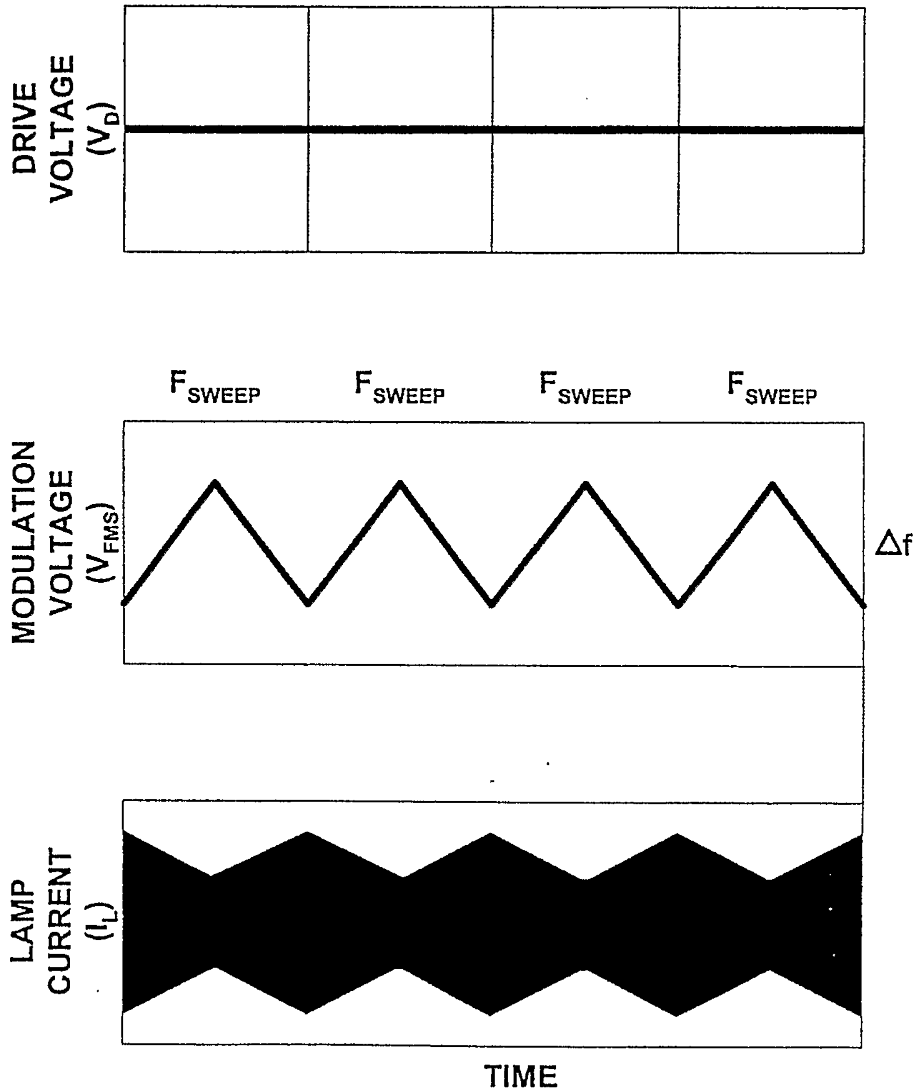

DRIVE VOLTAGE (V_D)
F_{SWEEP}
F_{SWEEP}
F_{SWEEP}
F_{SWEEP}
MODULATION VOLTAGE (V_{FMS})
Δf
LAMP CURRENT (I_L)
TIME

FIG. 5

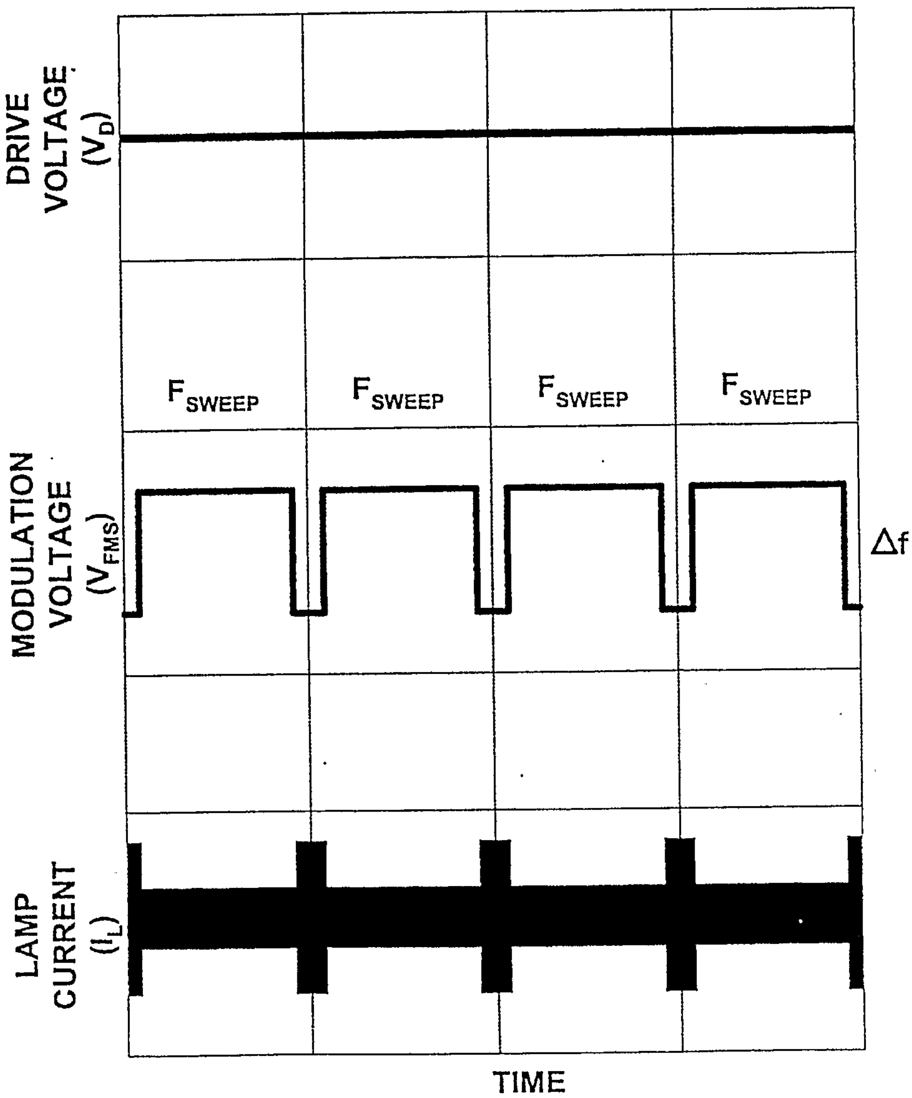

DRIVE VOLTAGE (V_D)
F_{SWEEP}
F_{SWEEP}
F_{SWEEP}
F_{SWEEP}
MODULATION VOLTAGE (V_{FMS})
Δf
LAMP CURRENT (I_L)
TIME

FIG. 6

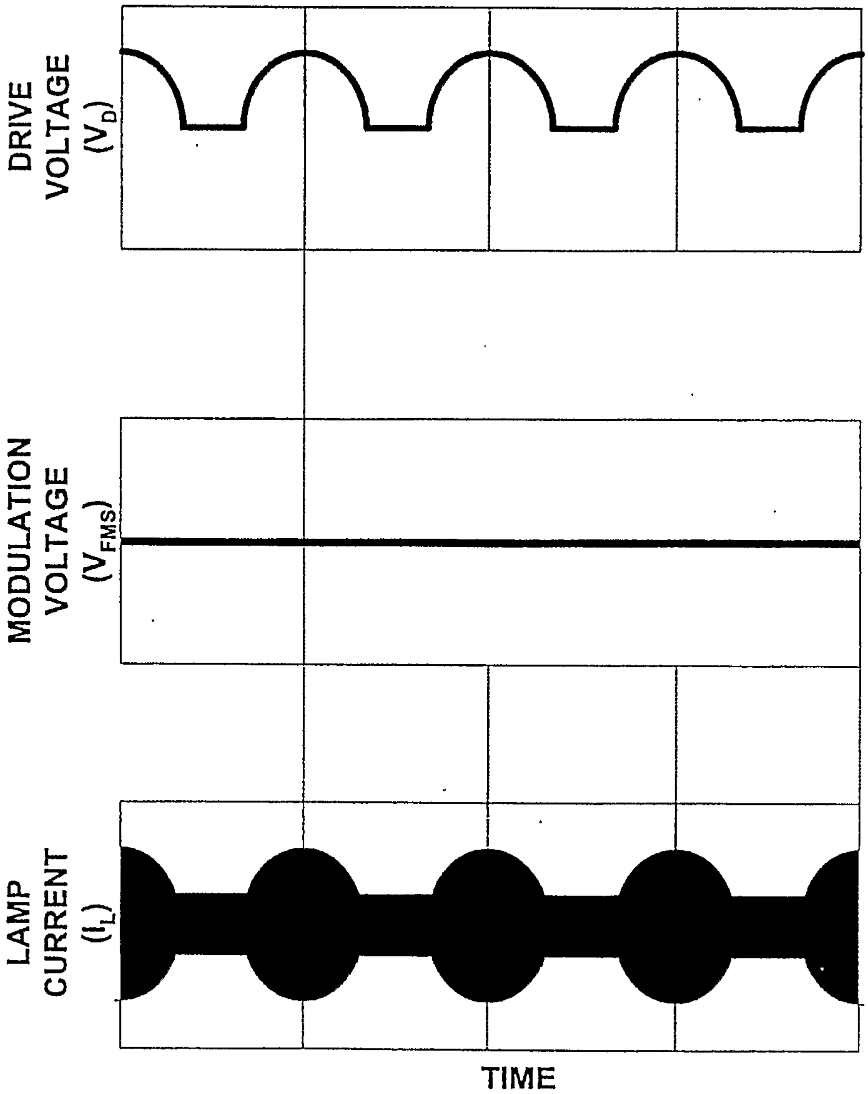

DRIVE VOLTAGE (V_D)
MODULATION VOLTAGE (V_{FMS})
LAMP CURRENT (I_L)
TIME

FIG. 7

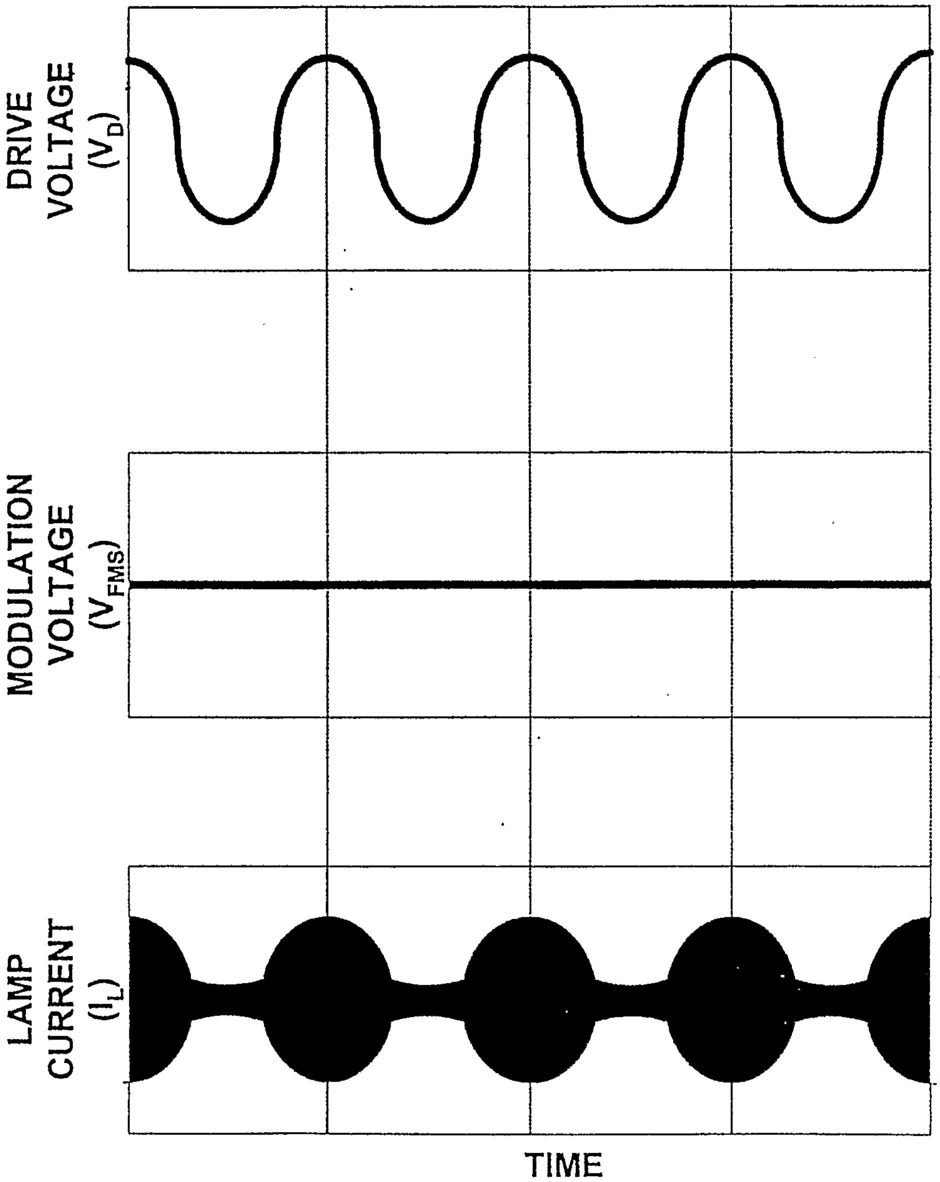

DRIVE VOLTAGE (V_D)
MODULATION VOLTAGE (V_{FMS})
LAMP CURRENT (I_L)
TIME

FIG. 8

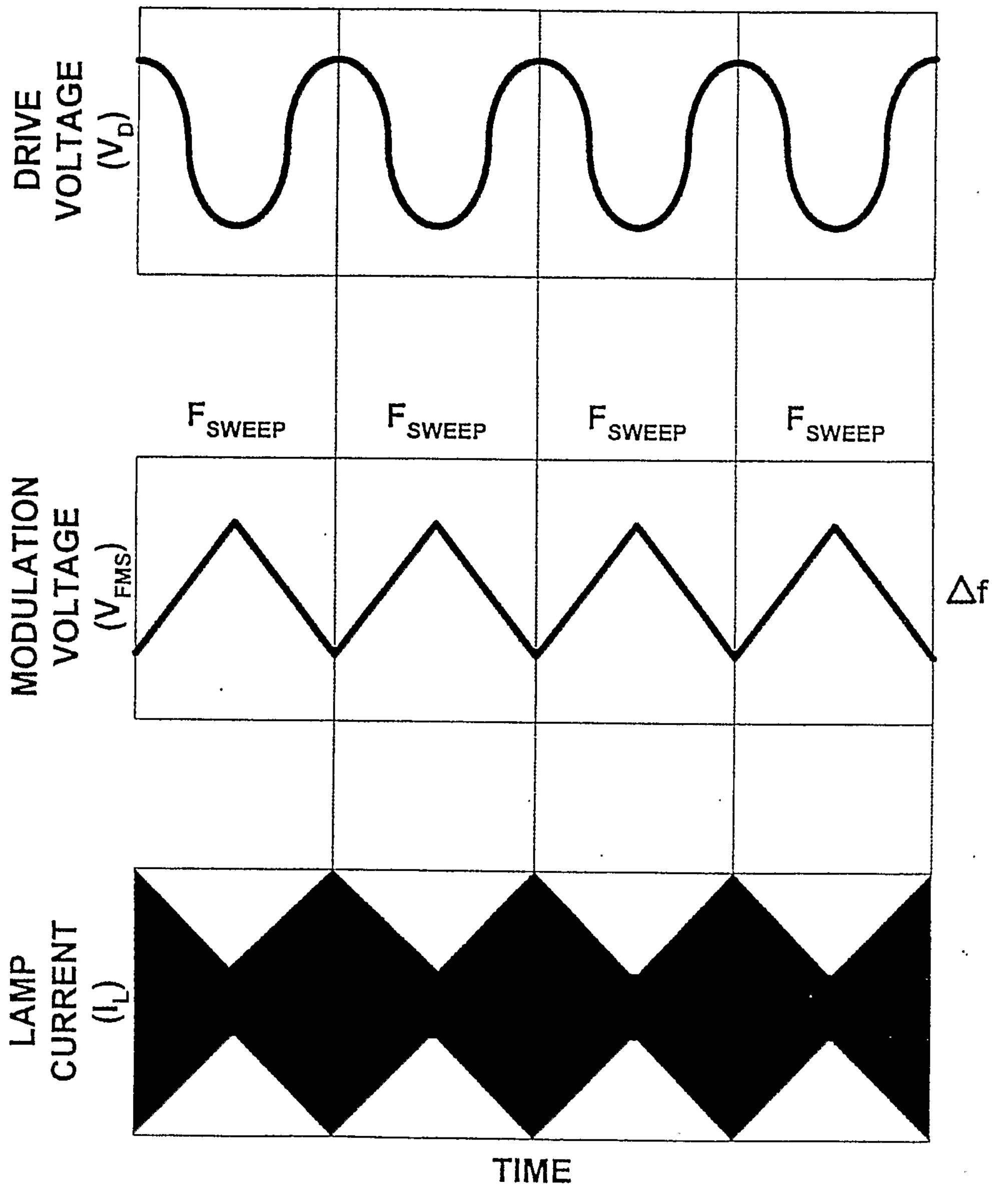

DRIVE VOLTAGE (V_D)
F_{SWEEP}
F_{SWEEP}
F_{SWEEP}
F_{SWEEP}
MODULATION VOLTAGE (V_{FMS})
Δf
LAMP CURRENT (I_L)
TIME

FIG. 9