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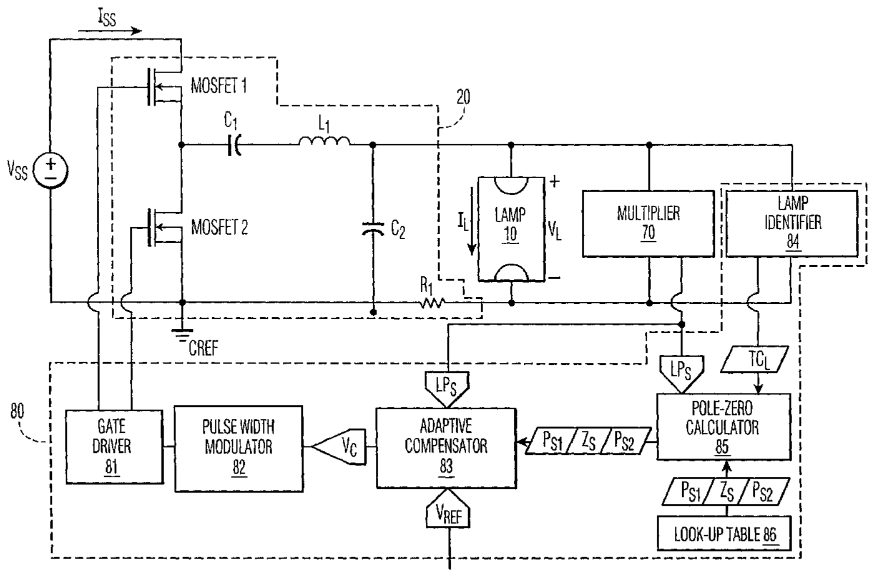
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ADAPTIVE CONTROL FOR HALF-BRIDGE UNIVERSAL LAMP DRIVERS



(57) Abstract: An adaptive compensation circuit (80, 90) for controlling a universal lamp driver (20) coupled to a lamp (10) is disclosed. The adaptive compensation circuit (80, 90) utilizes an identification of a lamp type of the lamp (10) to thereby generate a signal indicative of a time constant of the lamp (10). The adaptive compensation circuit (80, 90) subsequently determines a zero position (Z_S) and a pair of pole positions (P_{S1}, P_{S2}) corresponding to the time constant, and generates a control voltage (V_C) in response to a determination of the zero position (Z_S) and the pair of pole positions (P_{S1}, P_{S2}). The control voltage (V_C) facilitates an operation of the universal lamp driver (20) to stably provide a lamp current (I_L) to the lamp (10).

WO 03/022015 A1

Adaptive control for half-bridge universal lamp drivers

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to controlling a dimming of various types of lamps. The present invention specifically relates to hindering discontinuities and oscillations within a lamp due to the ionization and recombination time delay of the lamp.

2. Description of the Related Art

FIGS. 1 and 4 illustrates a known structural arrangement of a universal lamp driver 20 including a N-depletion metal oxide semiconductor field-effect transistor ("MOSFET 1"), a N-depletion metal oxide semiconductor field-effect transistor ("MOSFET 2"), a capacitor C_1, an inductor L_1, and a capacitor C_2 for providing a lamp voltage V_L and a lamp current I_L to lamp 10 in response to a source supply voltage V_{SS} and a source supply current I_{SS}. FIG. 1 further illustrates a conventional multiplier 30 and a known structural arrangement of a feedback compensation circuit 40 having a conventional gate driver 41, a conventional pulse width modulator 42, a comparator in the form of an operational amplifier ("OP AMP 1"), a capacitor C_3, and a resistor R_2. Multiplier 30 computes and provides a lamp power signal LP_S to feedback compensation circuit 40 that is indicative of lamp voltage V_L and lamp current I_L. In response to lamp power signal LP_S and a reference voltage V_{REF}, feedback compensation circuit 40 controls an active mode of operation of MOSFET 1 and an active mode of operation of MOSFET 2 whereby lamp current I_L can be adjusted to thereby adjust a dimming level of lamp 10.

An advantage of universal lamp driver 20 is the ability to drive various forms of lamp 10 (e.g., any type of gas discharge lamp). A disadvantage of feedback compensation circuit 40 is the inability to control an adjustment of lamp current I_L for all types of various forms of lamp 10. FIG. 2 illustrates the inability of feedback compensation circuit 40 to control an adjustment of lamp current I_L within an inaccessible area. The result is a discontinuity in lamp current I_L as illustrated in FIG. 3A.

FIG. 4 illustrates a rectifier 50 and a known structural arrangement of a feedback compensation circuit 60 having a conventional gate driver 61, a conventional voltage controlled oscillator 62, a comparator in the form of an operational amplifier ("OP AMP 2"), a capacitor C_4, a capacitor C_5, a resistor R_3, and a resistor R_4. Rectifier 50 computes and provides lamp power signal LC_S to feedback compensation circuit 60 that is indicative of lamp current I_L. In response to lamp current signal LC_S and reference voltage V_{REF}, feedback compensation circuit 60 controls an active mode of operation of MOSFET 1 and an active mode of operation of MOSFET 2 whereby lamp current I_L can be adjusted while experiencing a continuity as illustrated in FIG. 3B.

However, a disadvantage of feedback compensation circuit 60 is the inability to provide a compensation to half-bridge universal lamp driver 20 that is adapted to a particular type of lamp 10. The result is an instability problem of lamp driver 20 for some types of lamp 10. For example, feedback compensation circuit 60 can be designed to provide a 2 pole-1 zero compensation with a zero at 200 rad/sec and a pole at 10 rad/sec. Consequently, lamp current I_L can be unstable as illustrated in FIG. 5A when lamp 10 is a type of lamp having a time constant of 50 μ, and lamp current I_L can be stable as illustrated in FIG. 5B when lamp 10 is a type of lamp having a time constant of 500 μs.

The present invention addresses the shortcomings of the prior art.

SUMMARY OF THE INVENTION

The present invention relates to an adaptive control of universal lamp drivers. 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 method of adaptively controlling a lamp driver coupled to a lamp. First, a time constant corresponding to the lamp is determined. Second, the lamp driver is operated to provide a lamp current to the lamp as a function of the time constant of the lamp.

A second form of the present invention is a device comprising a lamp driver and an adaptive compensation circuit. The lamp driver is operable to provide a lamp current to a lamp. The adaptive compensation circuit is operable to control the lamp current as a function of a time constant of the 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 a universal lamp driver and a power feedback compensation circuit as known in the art;

FIG. 2 illustrates a graph of a lamp current vs a lamp voltage generated and controlled by the universal lamp driver and the power feedback compensation circuit of FIG. 1;

FIG. 3A illustrates a graph of a lamp current experiencing a discontinuity;

FIG. 3B illustrates a graph of a lamp current experiencing a continuity;

FIG. 4 illustrates a universal lamp driver and a current feedback compensation circuit as known in the art;

FIG. 5A illustrates a first graph of an unstable lamp current;

FIG. 5B illustrates a second graph of stable lamp current;

FIG. 6 illustrates a first embodiment of a universal lamp driver and an adaptive feedback compensation circuit in accordance with the present invention; and

FIG. 7 illustrates a second embodiment of a universal lamp driver and an adaptive feedback compensation circuit in accordance with the present invention.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

FIG. 6 illustrates universal lamp driver 20 as previously described herein in connection with FIG. 1 as well as a conventional multiplier 70 and an adaptive compensation circuit 80 in accordance with the present invention. Adaptive compensation circuit 80 comprises a conventional gate driver 81 and a conventional pulse width modulator 82. Adaptive compensation circuit 80 further comprises a lamp identifier 84, a pole-zero calculator 85, a look-up table 86, and an adaptive compensator 83, all of which can consist of digital circuitry, analog circuitry, or both.

Lamp identifier 84 is operable to provide a time constant signal TC_S that is indicative of a time constant of lamp 10 to pole-zero calculator 85 in response to lamp voltage V_L. In one embodiment, lamp identifier 84 generates time constant signal TC_S by identifying the type of lamp 10 as disclosed in a U.S. Patent No. 6,160,361, entitled "For Improvements In A Lamp Type Recognition Scheme" and issued on December 12, 2000, which the entirety of is hereby incorporated by reference and is owned by the assignee of this patent.

In response to time constant signal TC_S and lamp power signal LP_S, pole-zero calculator 85 is operable to retrieve a first pole position signal P_{S1}, a zero position signal Z_S, and a second pole position signal P_{S2} from look-up table 86, all of which correspond to the time constant of lamp 10. Pole position signal P_{S1} is indicative of a low frequency (e.g., 10-20 rad/sec). Pole position signal P_{S2} is indicative of a high frequency (e.g., 1,000-50,000 rad/sec). Zero position signal Z_S is indicative of a frequency between the low frequency indicated by pole position signal P_{S1} and the high frequency indicated by pole position signal P_{S2}. The following TABLE 1 is an exemplary embodiment of look-up table 86:

TABLE 1

TIME CONSTANT (μs)	LOW POLE POSITION (rad/sec)	ZERO POSITION (rad/sec)	HIGH POLE POSITIION (rad/sec)
50	10	600	10,000
500	10	200	1,000
200	10	430	4,600

Pole-zero calculator 85 provides pole position signal P_{S1}, zero position signal Z_S, and a second pole position signal P_{S2} to adaptive compensator 83. In response thereto as well as lamp power signal LP_S and a voltage reference V_{REF2}, adaptive compensator 83 computes a control voltage V_C for conventionally operating pulse width modulator 82 and gate driver 81 whereby lamp current I_L is continually and stably controlled as shown in FIGS. 3B and 5B. In one embodiment, adaptive compensator 83 computes control voltage V_C in accordance with the following Laplace transfer function [1] in a frequency domain:

$$K * [(S + Z_S)/\{(S + P_{S1}) * (S + P_{S2})\}] \qquad [1]$$

where K is the dc gain of the compensation which is adjusted by the feedback loop established by compensation circuit 80. Those having ordinary skill in the art will appreciate the circuitry illustrated in FIG. 6 is an open loop circuit prior to an identification of the type of lamp 10 and a closed load circuit upon an initial computation of control voltage V_C.

FIG. 7 illustrates universal lamp driver 20 and multiplier 70 as previously described herein in connection with FIG. 1 as well as an adaptive compensation circuit 90 in accordance with the present invention. Adaptive compensation circuit 90 comprises conventional gate driver 81, conventional pulse width modulator 82, pole-zero calculator 85, look-up table 86, and adaptive compensator 83 as previously described herein in connection with FIG. 6. Alternative to lamp identifier 85 (FIG. 6), adaptive compensation circuit 90 comprises a lamp identifier 87 that is operable to provide time constant signal TC_S to pole-zero calculator 85 in response to a lamp identification signal LID_S via as serial port or an RF interface from a central control unit.

In other embodiments of the present invention, an adaptive compensator based upon a current feedback control, multi-loop control, and frequency modulations can be substituted for adaptive compensator 83.

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 adaptively controlling a lamp driver (20) coupled to a lamp (10), said method comprising:

determining a time constant corresponding to the lamp (10); and

operating the universal lamp driver (20) to provide a lamp current (I_L) to the lamp (10) as a function of a time constant of the lamp (10).

2. A method of adaptively controlling a lamp driver (20) coupled to a lamp (10) as claimed in claim 1, said method comprising:

determining a zero position (Z_S), a first pole position (P_{S1}), and a second pole position (P_{S2}) in response to a determination of the time constant;

generating a control voltage (V_C) as a function of the zero position (Z_S), the first pole position (P_{S1}), and the second pole position (P_{S2}); and

operating the lamp driver (20) to stably provide a lamp current (I_L) to the lamp (10) in response to a generation of the control voltage (V_C).

3. A device, comprising:

a universal lamp driver (20) operable to provide a lamp current (I_L) to a lamp (10); and

an adaptive compensation circuit (80, 90) operable to control the lamp current (I_L) as a function of a time constant of the lamp (10).

4. The device of claim 3, wherein said adaptive compensation circuit (80, 90) includes means (84, 87) for determining the time constant corresponding to the lamp (10).

5. The device of claim 3, wherein said adaptive compensation circuit (80, 90) includes means (85) for determining a zero position (Z_S), a first pole position (P_{S1}), and a second pole position (P_{S2}) in response to a determination of the time constant.

6. The device of claim 5, wherein said adaptive compensation circuit (80, 90) includes means (83) for generating a control voltage (V_C) as a function of the zero position (Z_S),the first pole position (P_{S1}), and the second pole position (P_{S2}) corresponding to the lamp (10).

7. The device of claim 6, comprising means (81, 82) for operating the lamp driver (20) to stably provide a lamp current (I_L) to the lamp (10) in response to a generation of the control voltage (V_C).

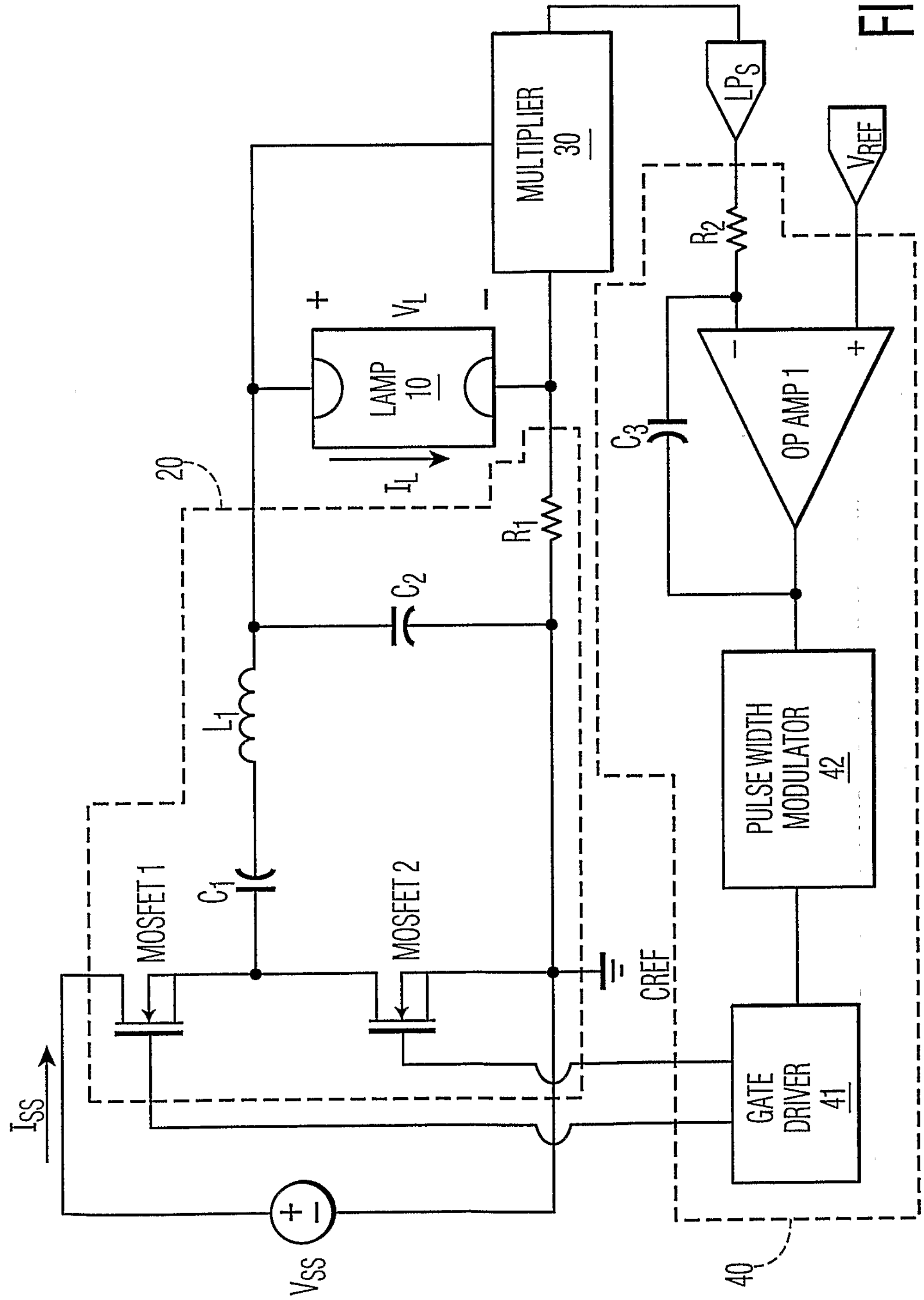

MULTIPLIER
30
LAMP
10
V_L
I_L
LP_S
V_{REF}
R_1
R_2
C_1
C_2
C_3
L_1
OP AMP 1
PULSE WIDTH
MODULATOR
42
GATE
DRIVER
41
MOSFET 1
MOSFET 2
CREF
I_{SS}
V_{SS}
20
40

FIG. 1

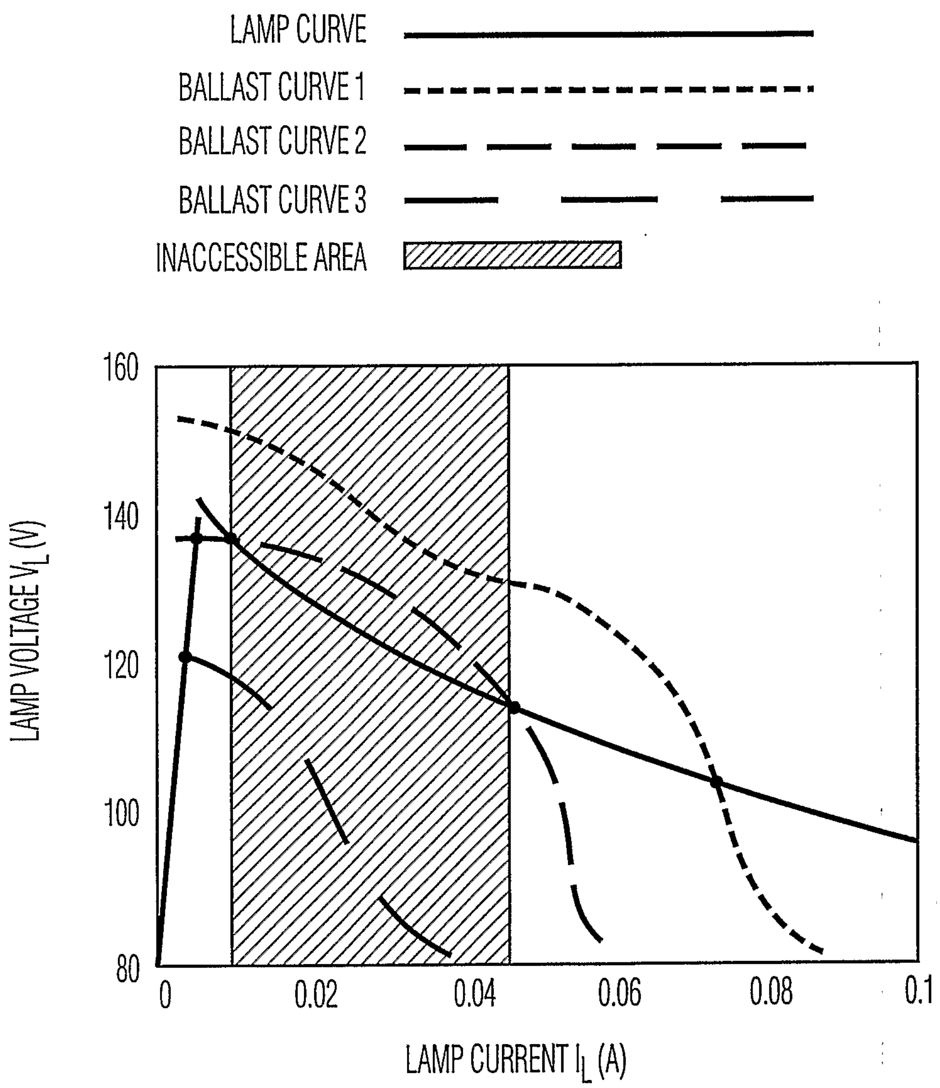

LAMP CURVE
BALLAST CURVE 1
BALLAST CURVE 2
BALLAST CURVE 3
INACCESSIBLE AREA
160
140
120
100
80
0
0.02
0.04
0.06
0.08
0.1
LAMP VOLTAGE V_L (V)
LAMP CURRENT I_L (A)

FIG. 2

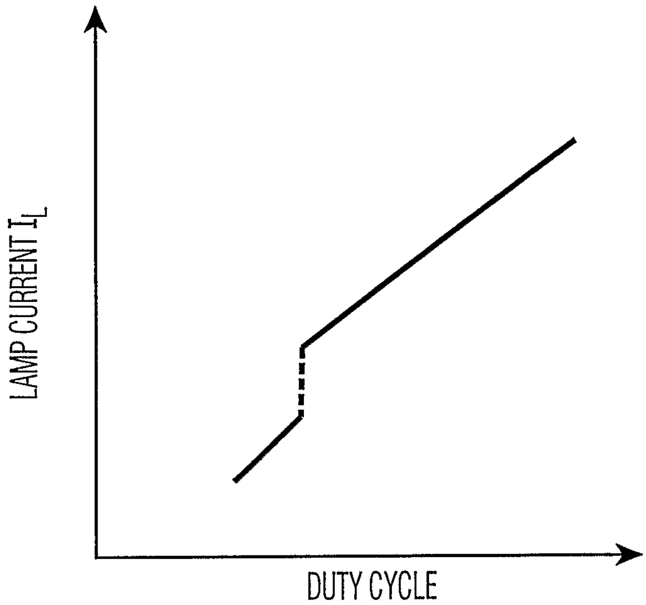


FIG. 3A

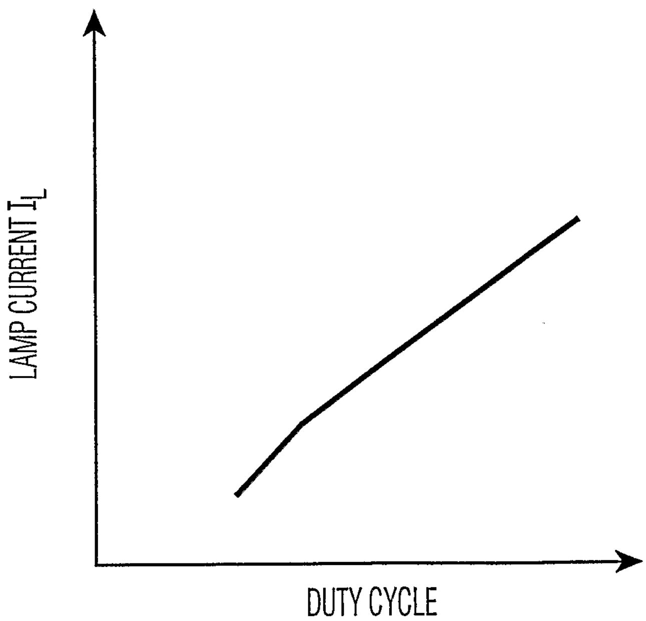


FIG. 3B

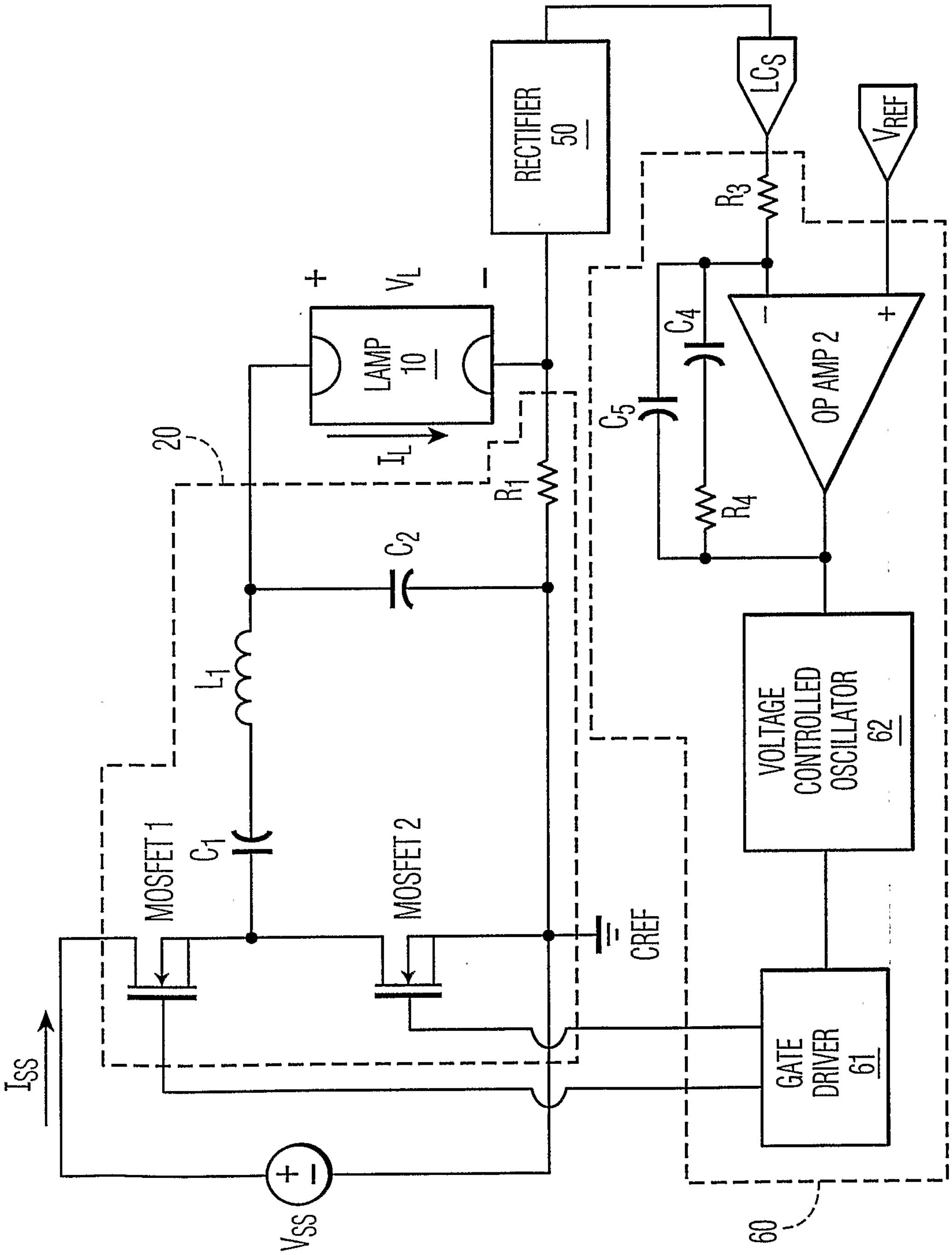

RECTIFIER
50
LCS
VREF
R3
C4
C5
R4
OP AMP 2
+
−
VL
LAMP
10
IL
20
R1
C2
L1
C1
MOSFET 1
MOSFET 2
CREF
ISS
VSS
VOLTAGE CONTROLLED OSCILLATOR
62
GATE DRIVER
61
60

FIG. 4

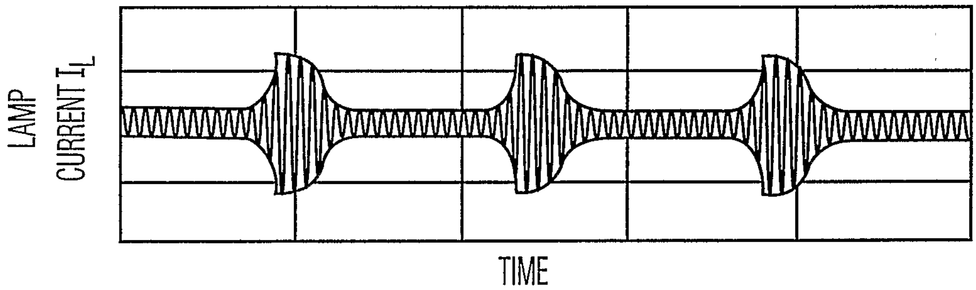


FIG. 5A

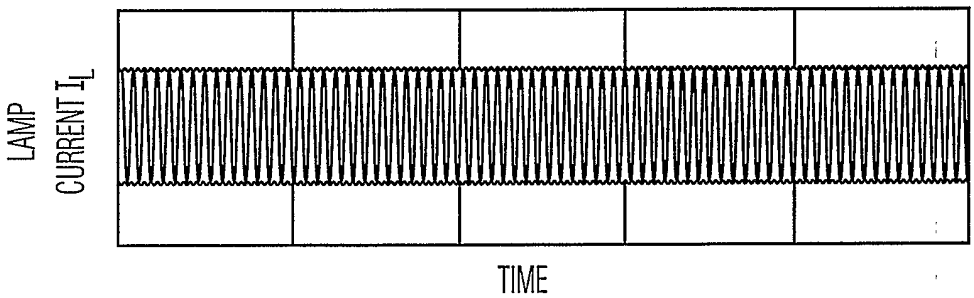


FIG. 5B

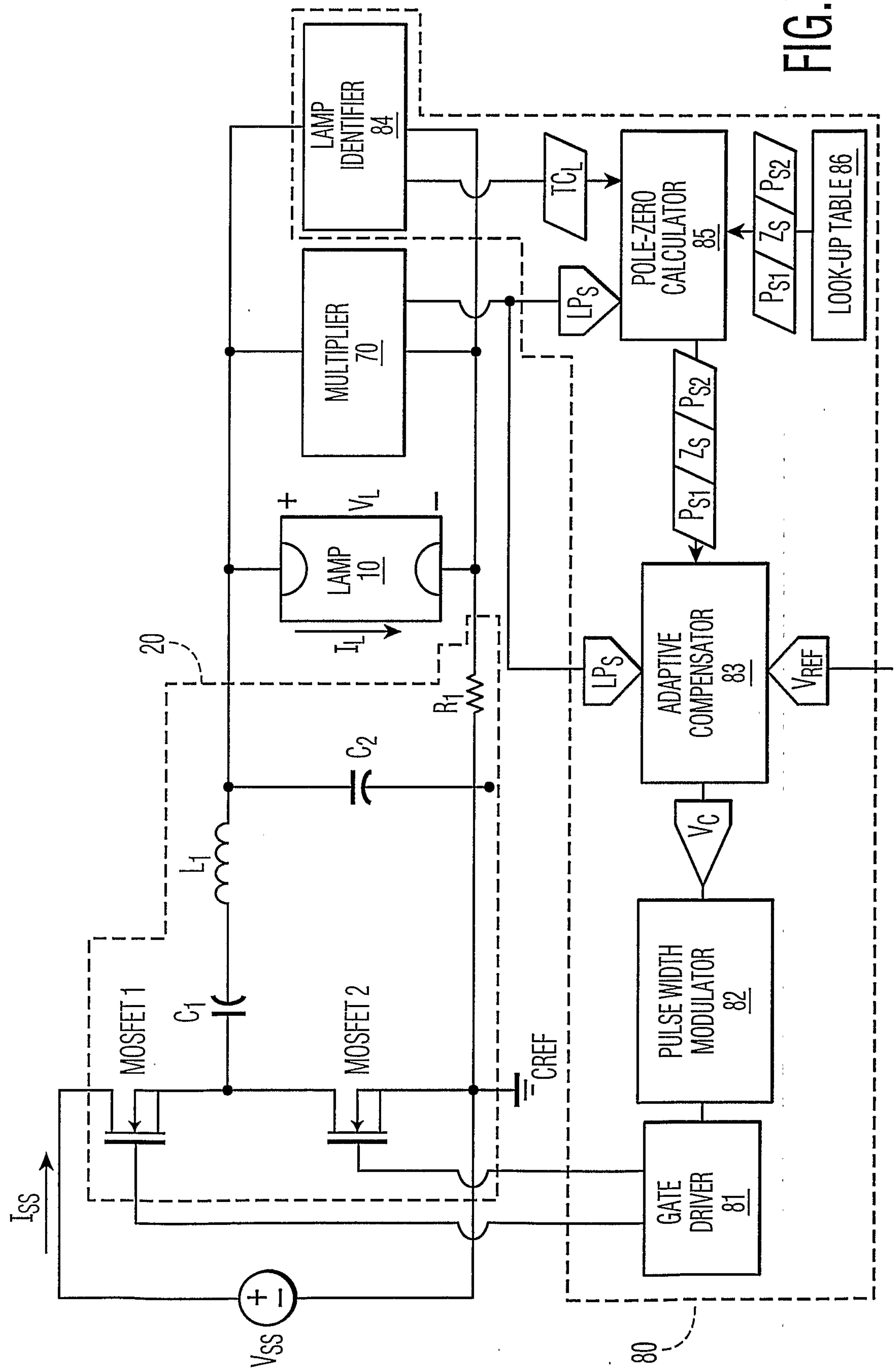

LAMP IDENTIFIER 84
POLE-ZERO CALCULATOR 85
LOOK-UP TABLE 86
MULTIPLIER 70
LAMP 10
ADAPTIVE COMPENSATOR 83
PULSE WIDTH MODULATOR 82
GATE DRIVER 81
MOSFET 1
MOSFET 2
CREF
20
80

FIG. 6

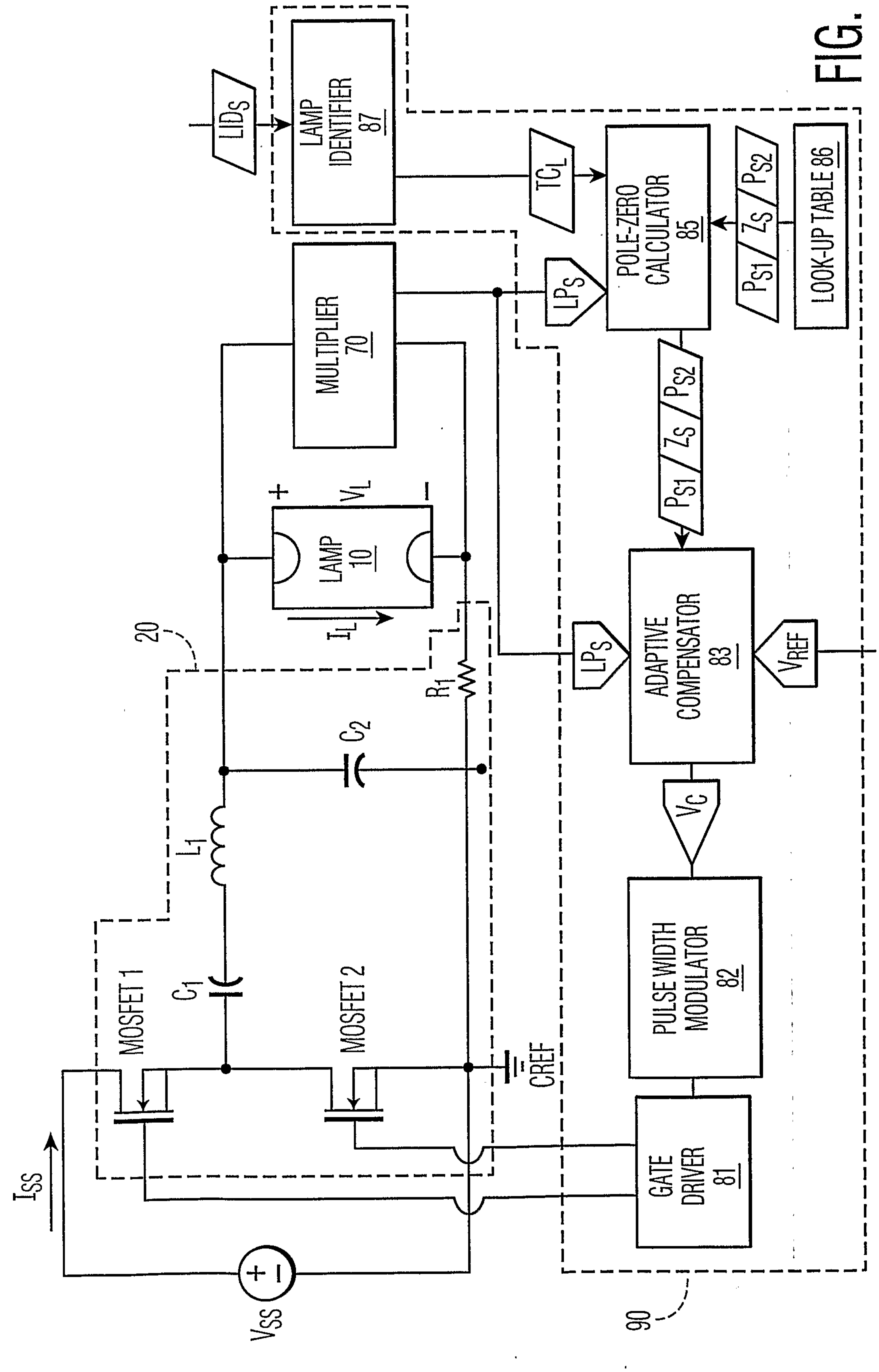

LIDS
LAMP IDENTIFIER 87
TCL
POLE-ZERO CALCULATOR 85
PS1 / ZS / PS2
LOOK-UP TABLE 86
MULTIPLIER 70
LPS
LAMP 10
VL
IL
20
R1
C2
L1
C1
MOSFET 1
MOSFET 2
CREF
ISS
VSS
ADAPTIVE COMPENSATOR 83
VREF
VC
PULSE WIDTH MODULATOR 82
GATE DRIVER 81
90

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 02/03508

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H05B41/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	claim 1	2,5-7

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A	the whole document	2,5-7

A	EP 0 605 052 A (PHILIPS ELECTRONICS NV) 6 July 1994 (1994-07-06) abstract the whole document	2,5-7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 November 2002	19/11/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ferla, M

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 1 041 862 A (MITSUBISHI ELECTRIC CORP ;MITSUBISHI LIGHTING FIXTURE CO (JP)) 4 October 2000 (2000-10-04) column 25, line 14 -column 35, line 2; examples 17,20 -----	1,3,4

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