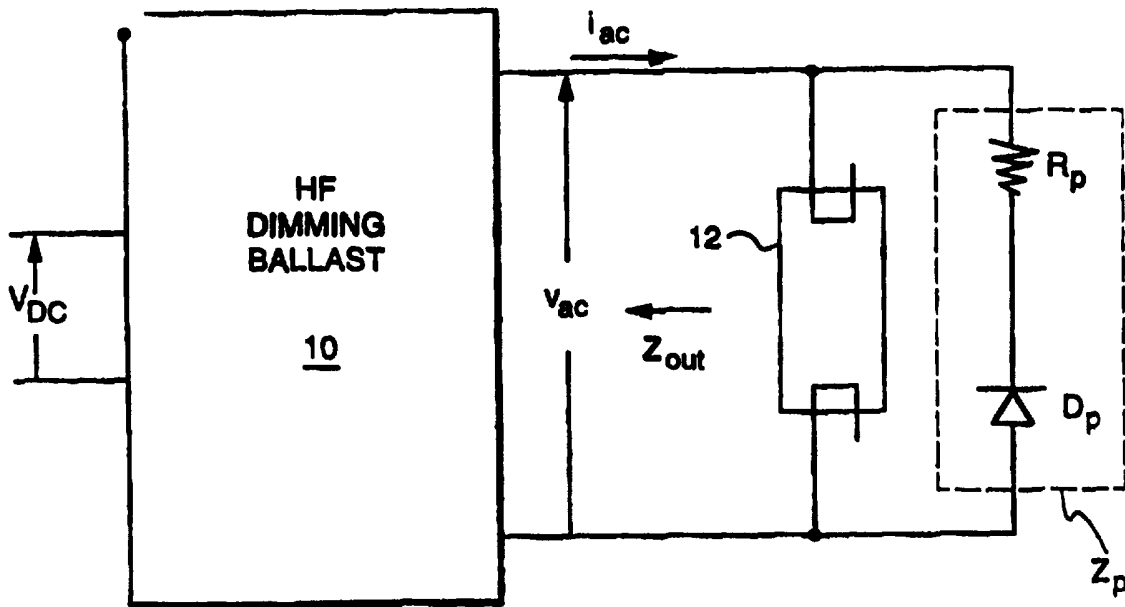




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<p>(21) International Application Number: PCT/US96/17290 (22) International Filing Date: 28 October 1996 (28.10.96) (30) Priority Data: 08/578,795 26 December 1995 (26.12.95) US (71) Applicant: GENERAL ELECTRIC COMPANY [US/US]; 3135 Easton Turnpike W3C, Fairfield, CT 06431 (US). (72) Inventors: STEIGERWALD, Robert, Louis; 3 Sandstone Drive, Burnt Hills, NY 12027 (US). STEVANOVIC, Ljubisa, Dragoljub; 3A Barney Road, Clifton Park, NY 12065 (US). (74) Agents: STECKLER, Henry, I. et al.; General Electric Company, 3135 Easton Turnpike W3C, Fairfield, CT 06431 (US).</p>		<p>(81) Designated States: JP, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i></p>

(54) Title: ELIMINATION OF STRIATIONS IN FLUORESCENT LAMPS DRIVEN BY HIGH-FREQUENCY BALLASTS



(57) Abstract

A ballast system for at least one dimmable fluorescent lamp includes a ballast inverter for driving the fluorescent lamp to provide light output and a parallel impedance for coupling across the fluorescent lamp for providing an alternative path for diverting sufficient dc current to avoid developing striated light output as the light output is dimmed. The parallel impedance may be a resistor connected in series with a diode. For multiple lamp systems, the parallel impedance may be connected across one or more of the lamps.

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ELIMINATION OF STRIATIONS IN
FLUORESCENT LAMPS DRIVEN BY
HIGH-FREQUENCY BALLASTS

Field of the Invention

5 The present invention relates generally to fluorescent lamps and, more particularly, to dimmable fluorescent lamps driven by high-frequency electronic ballasts.

Background of the Invention

10 A problem with dimmable fluorescent lamps is that for low light outputs (e.g., below about 20% full output), the high-frequency discharge current applied by electronic ballasts sometimes causes a standing wave of varying charge densities called striations. Striations are manifested as alternating bands of dim and bright light output along the length of the lamp. One way to avoid striations is to inject a small dc current into the lamp, e.g., on
15 the order of 1 mA. For example, in "Development of an Electronic Dimming Ballast for Fluorescent Lamps", *Journal of the Illuminating Engineering Society*, Winter 1992, A. Okude et al. describe injecting such a small dc current into the lamp using a power supply connected in series with an inductor and a diode, the series circuit being coupled across the lamp. Although this circuitry
20 does eliminate striations, it disadvantageously requires the additional power supply and inductor.

 Another way to avoid striations, as described in U.S. Pat. No. 5,001,386 of Sullivan et al., issued March 19, 1991, is to employ a circuit which creates an asymmetrical lamp current waveform having positive and
25 negative portions which are identical in shape, but which is offset from the zero current level. To this end, Sullivan et al. use a back end rectifier circuit including a capacitor, a pair of resistors, and a diode. The capacitor is connected between and in series with two secondary windings of the output transformer and in series with the lamp(s). One resistor is connected in series with the
30 diode to charge the capacitor to a dc voltage. This dc voltage causes a dc current

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FIG. 2 schematically illustrates a dimmable fluorescent lamp system according to one embodiment of the present invention;

FIG. 3 schematically illustrates a dimmable fluorescent lamp system according to an alternative embodiment of the present invention;

5 FIG. 4 schematically illustrates a dimmable fluorescent lamp system according to another alternative embodiment of the present invention;

FIG. 5 schematically illustrates a dimmable fluorescent lamp system according to another alternative embodiment of the present invention;

10 FIG. 6 schematically illustrates a dimmable fluorescent lamp system according to another alternative embodiment of the present invention; and

FIG. 7 schematically illustrates a dimmable fluorescent lamp system according to another alternative embodiment of the present invention.

Detailed Description of the Invention

15 FIG. 1 illustrates a dimmable fluorescent lamp system including a high-frequency electronic dimming ballast 10 and a lamp 12 having two filaments 14a and 14b. Each filament has a voltage source 16a and 16b, respectively, coupled thereacross for sustaining the filament voltage V_{FIL} during lamp operation. High-frequency dimming ballast 10 has a high output
20 impedance $Z_{out} = \frac{V_{ac}}{i_{ac}}$ and acts as a current source feeding current i_{ac} to the lamp 12. The high-frequency dimming ballast could be any well-known ballast circuit capable of operating the lamp in a range from 100% to about 1% full light output. The lamp of FIG. 1 is illustrated as having striations 13 that are developed at low output light levels (e.g., below about 20% full output).

25 FIG. 2 illustrates a dimmable fluorescent lamp system according to the present invention. A parallel impedance Z_p is connected across the lamp 12 to provide a path for diverting a small current during one-half of each high-frequency cycle, thereby causing a small dc current to be in the lamp. The dc current prevents the development of striations as the light

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output is dimmed. The parallel impedance is illustrated in FIG. 2 as comprising a diode D_p connected in series with a resistor R_p . Alternative embodiments of the parallel impedance Z_p are possible, such as, for example, an inductor in series with a diode.

5 In operation, during the positive half-cycle of the ac current i_{ac} from the ballast, the current i_{ac} flows only through the lamp due to the orientation of the diode in the illustrated circuit of FIG. 2. However, during the negative half-cycle of the current i_{ac} , a portion of the current is diverted through the parallel impedance Z_p . As a result, a small dc current is present in the lamp
10 and hence striations are avoided. If, as an alternative embodiment, the diode were oriented in the opposite way with its cathode connected to ground, then operation would be similar except that the negative half-cycle of the current i_{ac} would flow through the lamp with current being diverted through the parallel impedance Z_p during the positive half-cycle. In either case, striations are
15 avoided.

FIG. 3 illustrates a dimmable fluorescent lamp system according to the present invention including a more detailed schematic representation of the ballast 10. Furthermore, FIG. 3 illustrates a two-lamp system with fluorescent lamps 12 and 22. It is to be understood, however, that
20 the present invention applies to fluorescent lamp systems having one or more lamps. The ballast inverter 10 is shown schematically as comprising a conventional half-bridge ballast configuration for a fluorescent lamp. A capacitor C_1 , typically electrolytic, is coupled across the ballast input in order to provide a rectified, filtered dc voltage to a half-bridge connection of switching
25 devices Q1 and Q2. This input is typically obtained from rectifying an ac utility voltage. Alternatively, it can be obtained directly from a dc source such as a battery. A gate driver circuit (not shown) alternately switches devices Q1 and Q2 to provide bi-directional current flow through a resonant load circuit, including an inductor L1 and a capacitor C4, which is shown as being coupled
30 through an output transformer T_o and a capacitor C2 to the junction between the switching devices Q1 and Q2. The series-connected lamps 12 and 22 are connected in parallel across series-connected capacitors C3 and C4. The capacitor C3 is used to extend the dimming range of the ballast by changing

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resonant characteristics of the resonant circuit after the lamp starts. A resistor R3 is provided as a current sensor for controlling the lamp dimming function in a manner well-known in the art. A starting capacitor C5 is connected between the junction joining the lamps and ground, which momentarily shorts the lamp
5 22 during starting so that a higher voltage is applied to the lamp 12 for starting.

In the embodiment of FIG. 3, the parallel impedance Z_P is connected across only one of the lamps. Although the parallel impedance Z_P is shown as being connected across the upper lamp 12, it could alternatively be connected across the lower lamp 22. In either case, in accordance with the
10 present invention, it is sufficient to couple a parallel impedance across only one of the lamps in a multiple lamp system to avoid striations.

FIGs. 4-7 illustrate alternative embodiments of the dimmable fluorescent lamp system of the present invention as viewed from terminals *a* and *b* of FIG. 3. FIG. 4 shows parallel impedances Z_{P1} and Z_{P2} , respectively,
15 connected across each lamp 12 and 22, respectively. Specifically, each parallel impedance in FIG. 4 is shown as comprising a diode D_{P1} and D_{P2} , respectively, connected in series with a resistor R_{P1} and R_{P2} , respectively, with the diodes D_{P1} and D_{P2} oriented to conduct current in the same direction.

FIG. 5 is an alternative embodiment of FIG. 4 with inductors
20 L_{P1} and L_{P2} , respectively, substituted for the resistors R_{P1} and R_{P2} , respectively.

FIG. 6 illustrates another alternative embodiment with a parallel impedance Z_P connected across each lamp 12 and 22, but with the diodes D_{P1} and D_{P2} , respectively, oriented to conduct current in opposite directions.
25 During normal operation of the dimmable fluorescent lamp system, the current i_{ac} flows through the series connection of lamps 12 and 22, while only a small portion of the current i_{ac} flows through the starting capacitor C5. Also, during the positive half-cycle of the current i_{ac} , a small portion of the total current i_{ac} will flow through the impedance Z_{P2} connected in parallel to the lamp 22.
30 During the negative half-cycle of the current i_{ac} , a small portion of the total current will flow through the impedance Z_{P1} connected in parallel to the lamp

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12. Therefore, both lamps will have a small dc current and striations are avoided.

FIG. 7 illustrates another alternative embodiment of a multiple lamp system wherein a parallel impedance Z_{P3} is connected across the series combination of both lamps. In this embodiment, as shown, there is an additional parallel impedance Z_{P1} coupled across one of the lamps. As in the other embodiments described hereinabove, the diodes may either be oriented to conduct current in the same direction (i.e., either one) or opposite directions.

10 While the preferred embodiments of the present invention have been shown and described herein, it will be obvious that such embodiments are provided by way of example only. Numerous variations, changes and substitutions will occur to those of skill in the art without departing from the invention herein. Accordingly, it is intended that the invention be limited only
15 by the spirit and scope of the appended claims.

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WHAT IS CLAIMED IS:

1. A ballast system for at least one dimmable fluorescent lamp, comprising:

a ballast inverter for driving said at least one dimmable fluorescent lamp to provide light output; and

5 a parallel impedance for coupling across said at least one fluorescent lamp for providing an alternative path to divert sufficient dc current to avoid developing striated light output.

2. The ballast system of claim 1 wherein said parallel impedance comprises a resistor connected in series with a diode.

3. The ballast system of claim 1 wherein said parallel impedance comprises an inductor connected in series with a diode.

4. The ballast system of claim 1 wherein said ballast inverter comprises a resonant switching inverter.

5. The ballast system of claim 1 for driving at least two dimmable fluorescent lamps, said parallel impedance being coupled across one of said lamps.

6. The ballast system of claim 1 for driving at least two dimmable fluorescent lamps, said parallel impedance being coupled across each of said lamps.

7. The ballast system of claim 5 wherein each said parallel impedance comprises a diode connected in series with a resistor.

8. The ballast system of claim 7 wherein said diodes of said parallel impedances are oriented to conduct current in the same direction.

9. The ballast system of claim 8 wherein said diodes of said parallel impedances are oriented to conduct current in opposite directions.

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10. The ballast system of claim 1 for driving at least two dimmable fluorescent lamps, said parallel impedance being coupled across the combination of both lamps.

11. The ballast system of claim 10 wherein an additional parallel impedance is coupled across one of said lamps.

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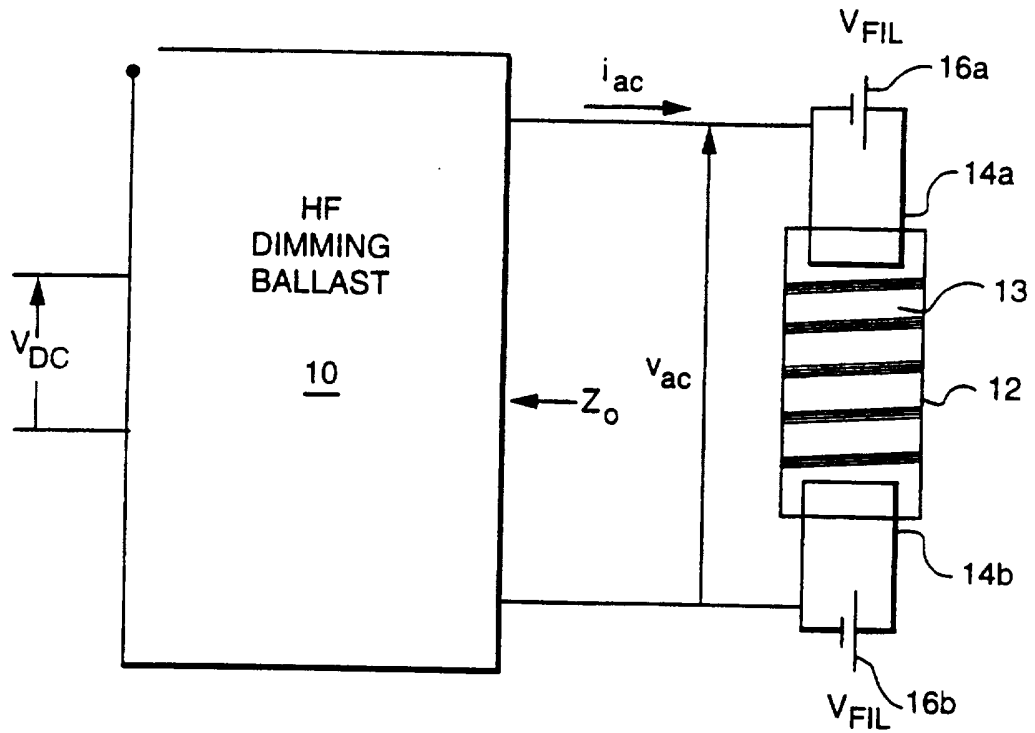


FIG. 1
PRIOR ART

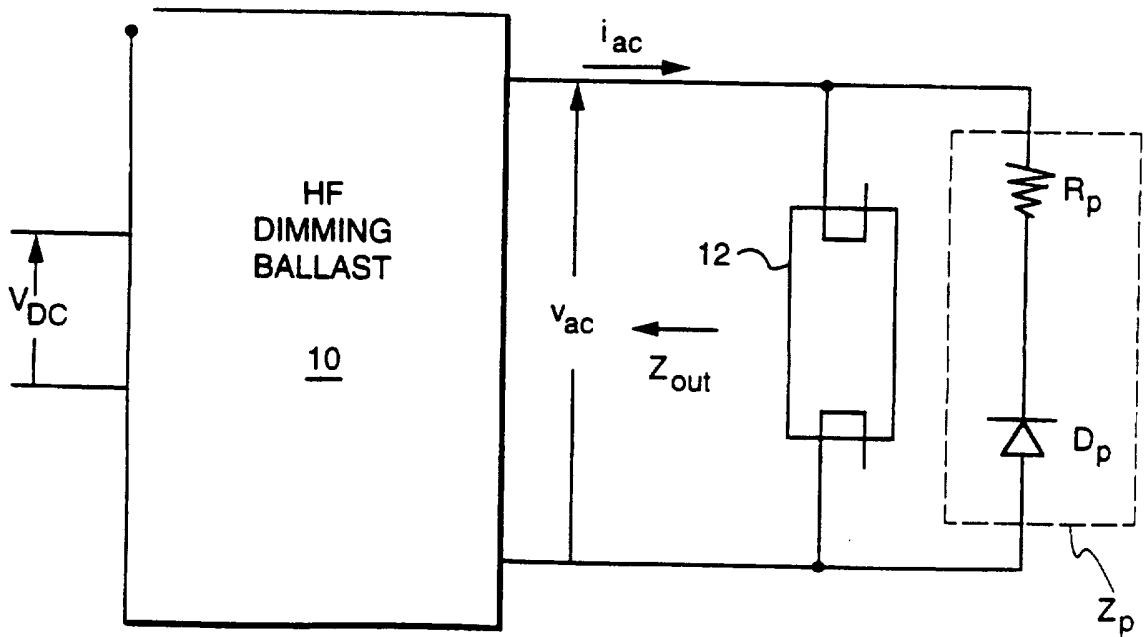


FIG. 2

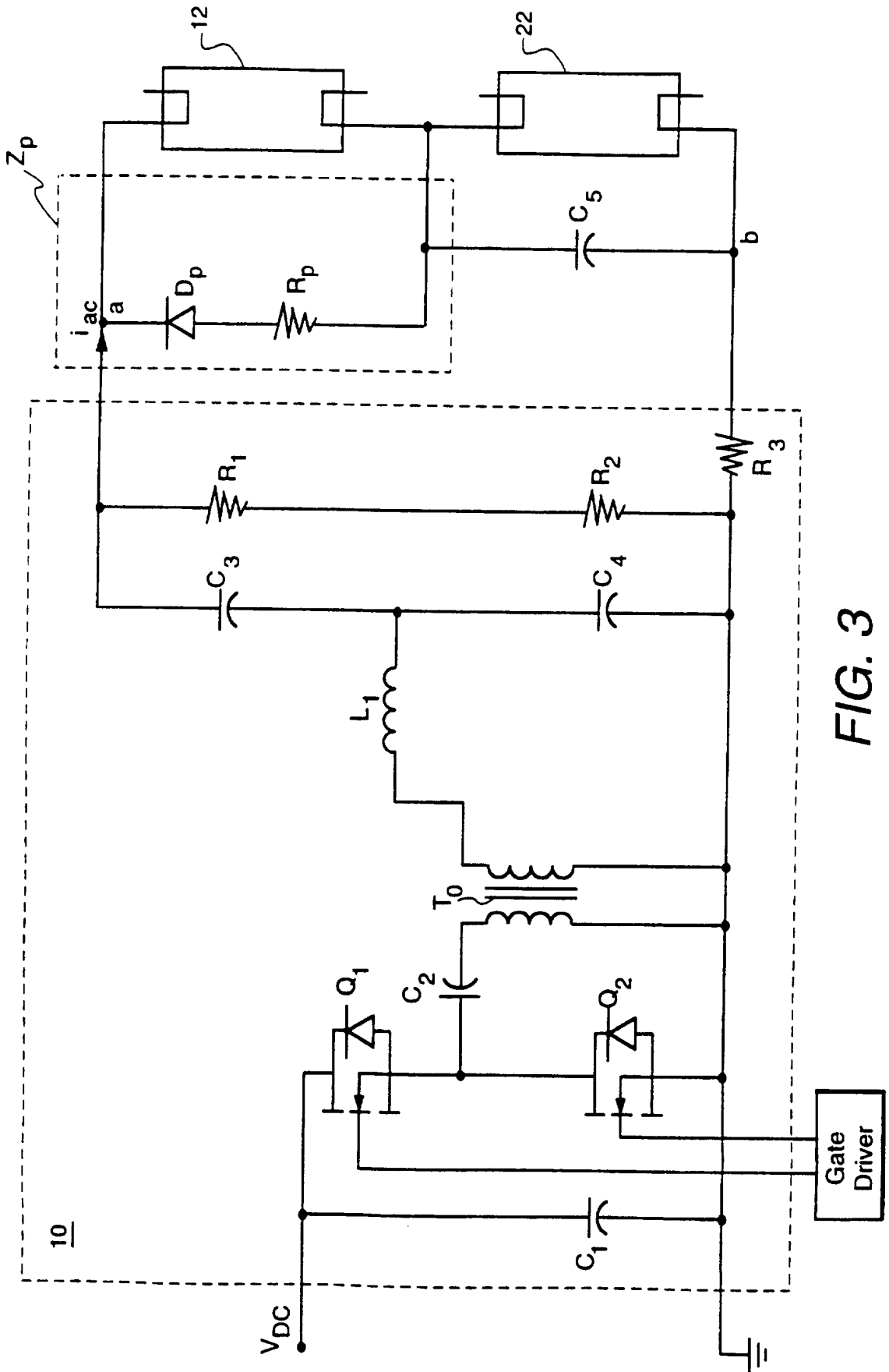


FIG. 3

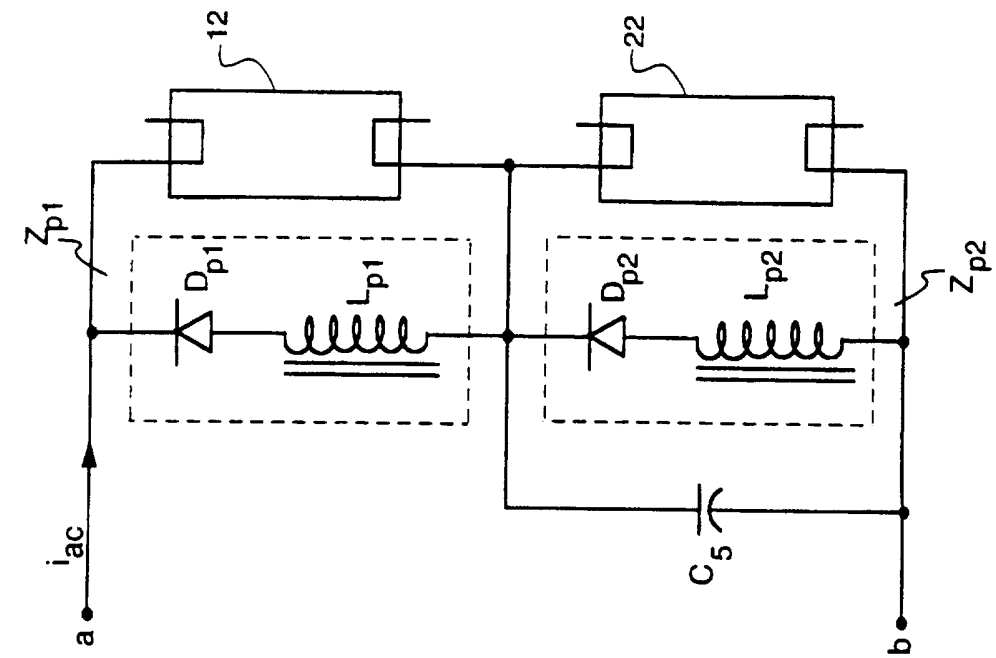


FIG. 5

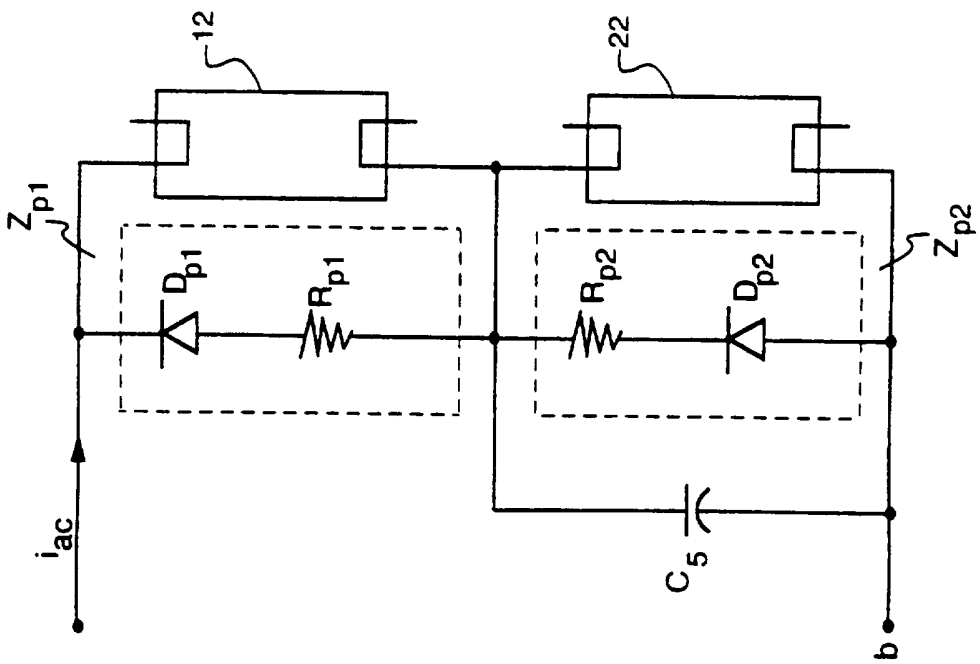


FIG. 4

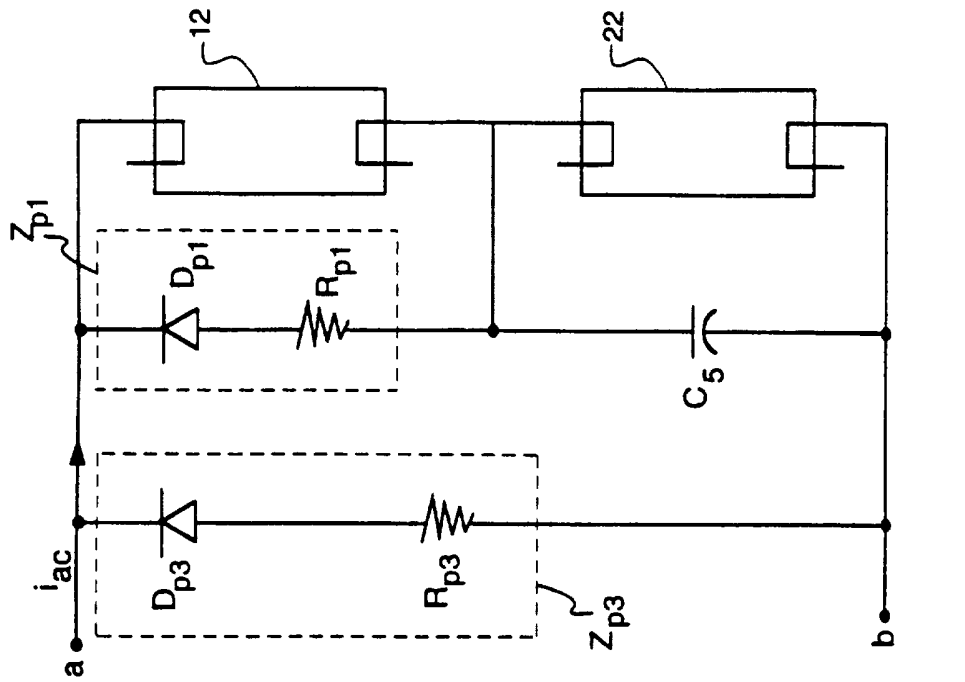


FIG. 7

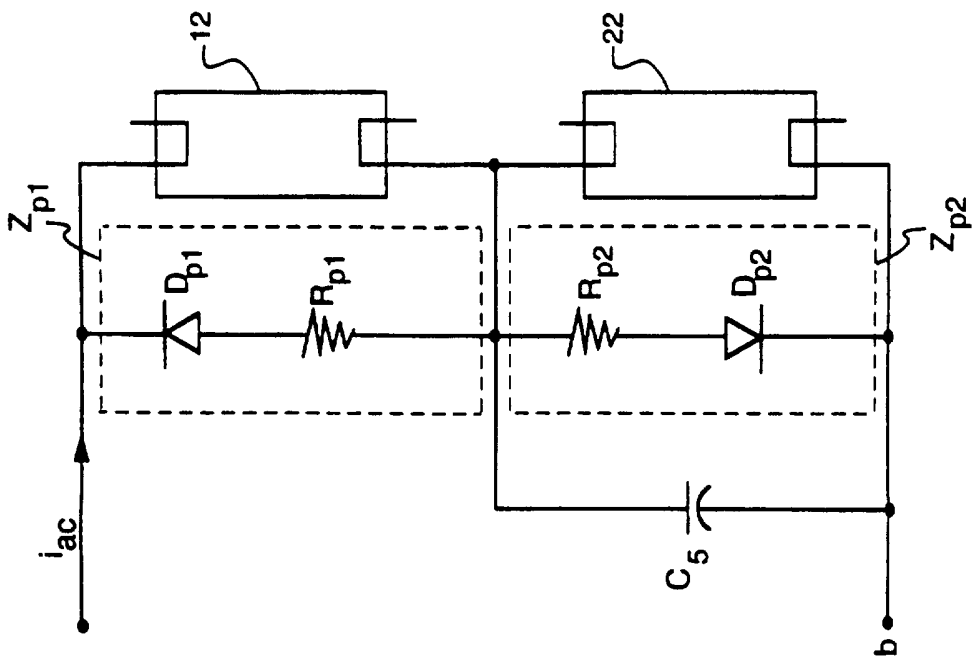


FIG. 6

INTERNATIONAL SEARCH REPORT

Inter: nal Application No
PCT/US 96/17290

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05B41/29

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 6 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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 547 674 (PHILIPS NV) 23 June 1993 see the whole document ---	1,2,4,5, 7
X	US,A,5 001 386 (SULLIVAN CHARLES R ET AL) 19 March 1991 see column 2, line 39 - column 3, line 29; figure 3 ---	1-8,10
X	US,A,5 192 896 (QIN KONG) 9 March 1993 see abstract; figure 2 -----	1-3

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0547674	23-06-93	JP-A- 5251191 US-A- 5369339	28-09-93 29-11-94

US-A-5001386	19-03-91	CA-A- 2032058 DE-A- 4039497 GB-A,B 2239568 JP-A- 4112494 US-A- 5041763	23-06-91 27-06-91 03-07-91 14-04-92 20-08-91

US-A-5192896	09-03-93	NONE	
