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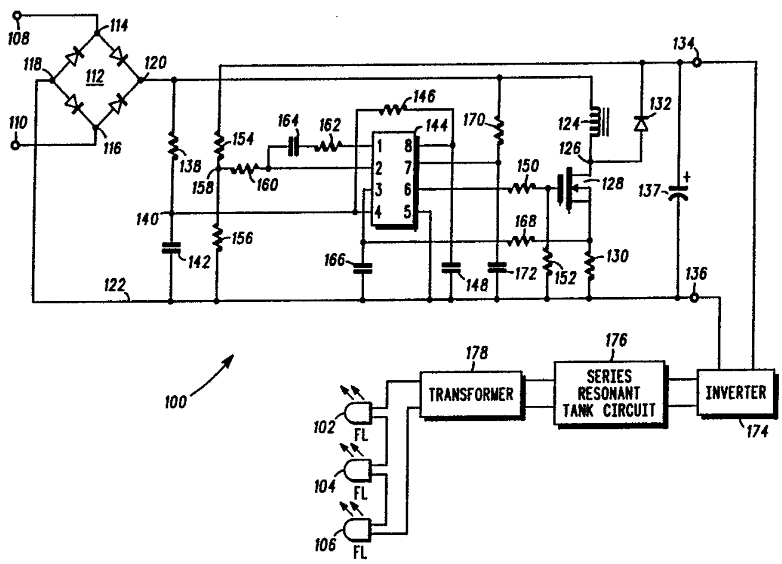

(57) Abstract

A voltge boost power supply, for use in a fluorescent lamp ballast (100), having: an inductance (170) coupled between an alternating supply voltage input (108, 110) and an output (134, 136), a switch (128) for controlling the current carried by the inductance, and a current-mode control IC (144) for producing a PWM control signal to control the switch so as to control the current carried by the inductance and thereby control the voltage across the inductance. The current-mode control IC is coupled (138) to the input so that the frequency of the control signal is modulated in accordance with the alternating supply voltage whereby the frequency of the control signal has a maximum value when the magnitude of the alternating supply voltage is a maximum. The power supply thus exhibits reduced harmonic distortion and increased power factor.

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POWER SUPPLY HAVING HIGH POWER FACTOR WITH CONTROL THAT TRACKS THE INPUT ALTERNATING SUPPLY

Field of the Invention

This invention relates to power supplies, and particularly, though not exclusively, to voltage boost power supplies for use in driving gas discharge lamps such as fluorescent lamps.

Background of the Invention

Gas discharge lamps are non-linear, negative resistance loads and so need to be driven from a ballast circuit. Such a ballast circuit typically incorporates a power supply which is itself supplied from a low frequency supply (e.g. a 60Hz utility mains).

Such a ballast circuit should ideally exhibit a high power factor (the ratio of the output power and input power, i.e. the ratio of the power delivered to the lamps and the power taken from the mains) and low harmonic distortion (introduction into the mains of frequencies different from the mains frequency).

It is known in such ballast circuits to use a power supply which boosts the mains voltage, e.g. at lamp start-up, by employing a boost inductor whose current is controlled by a switch (e.g. a field-effect transistor) which is in turn controlled by a pulse-width-modulated (PWM) signal. When, at the end of each PWM pulse, the switch turns OFF, the inductive current in the boost inductor generates an increased voltage. The PWM signal is typically generated in a current-mode control integrated circuit (IC). Such current-mode control IC's are well known in the art.

It is known in such power supplies to sense the output voltage, the inductor current and the line current and to generate therefrom a control signal to control (e.g. via a multiplier circuit) the PWM signal in order to improve the circuit's power factor. However, such known arrangements typically require special IC's to accomplish this additional control function.

Summary of the Invention

In accordance with a first aspect of the invention there is provided a power supply comprising:

an input for receiving an alternating supply voltage;

an output for producing a voltage derived from the supply voltage;

voltage producing means coupled between the input and the output for carrying a current and for producing a voltage therefrom;

switch means for controlling the current carried by the voltage producing means; and

control signal generating means for producing a pulsed control signal to control the switch means so as to control the current carried by the voltage producing means and thereby control the voltage produced thereby,

the improvement comprising modulating means coupled between the input and the control signal generating means for modulating the frequency of the control signal in accordance with the alternating supply voltage whereby the frequency of the control signal has a maximum value when the magnitude of the alternating supply voltage is a maximum so as to cause the current carried by the voltage producing means to have a waveform which approximates to that of the alternating supply voltage.

It will be appreciated that by causing the current carried by the voltage producing means to vary in accordance with the alternating supply voltage in this way, thereby causing the voltage producing means to present a load which varies in accordance with the alternating supply voltage, the power supply produces low harmonic distortion and exhibits a high power factor.

In accordance with a second aspect of the invention there is provided a power supply for converting an AC voltage into a DC voltage, said power supply having:

a full wave rectifier coupled to said AC voltage, means for producing a pulse width modulated signal, said means having a control input, and means controlled by said signal for producing said DC voltage,

the improvement comprising means for coupling said control input to the full wave rectifier to cause the frequency of said pulse width modulated signal to vary in accordance with the magnitude of said AC voltage whereby the frequency of said pulse width modulated signal has a maximum value when the magnitude of said AC voltage is a maximum, thereby obtaining high power factor and low harmonic distortion.

Brief Description of the Drawings

One circuit for driving fluorescent lamps and incorporating a power supply in accordance with the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 shows a partially block-schematic circuit diagram of the fluorescent lamp drive circuit;

FIG. 2 shows the waveform of the supply line voltage applied to the circuit;

FIG. 3 shows the waveform of the line current drawn by the circuit; and

FIG. 4 shows the waveform of line current drawn by a modified form of the circuit, not incorporating the present invention.

Description of the Preferred Embodiment

Referring now to FIG. 1, a circuit 100, for driving three fluorescent lamps 102, 104, 106, has two input terminals 108, 110 for receiving thereacross an AC supply voltage of approximately 277V at a frequency of 60Hz. A full-wave rectifying bridge circuit 112 has two input nodes 114, 116 connected respectively to the input terminals 108, 110, and has two output nodes 118, 120. The output node 118 of the bridge 112 is connected to a ground voltage rail 122.

A cored inductor 124 (having an inductance of approximately 4.5mH) has one end connected to the output node 120 of the bridge 112, and has its other end connected to a node 126. A field effect transistor (FET) 128 (of the type BUZ90) has its drain electrode connected to the node 126. The field effect transistor (FET) 128 has its source electrode connected, via a resistor 130 (having a value of approximately 1.6Ω), to the ground voltage rail 122. A diode 132 (of the type MUR160) has its anode connected to the node 126 and has its cathode connected to an output terminal 134. The ground voltage rail 122 is connected to an output terminal 136. An integrating capacitor 137 is connected between the output terminals 134 and 136.

A resistor 138 (having a resistance of approximately 2MΩ) is connected between the output node 120 of the bridge 112 and a node 140. A capacitor 142 (having a capacitance of approximately 0.0039μF) is connected between the node 140 and the ground voltage rail 122. A current-mode control integrated circuit (IC) 144 (of the type AS3845, available from ASTEC Semiconductor) has its R_T/C_T input (pin 4) connected to the node 140. The current mode control IC 144 has its V_{REG} output (pin 8) connected, via a resistor 146 (having a resistance of approximately 10KΩ), to the node 140 and connected, via a capacitor 148 (having a capacitance of approximately 0.22μF) to the ground voltage rail 122. The current mode control IC 144 has its control signal output (pin 6) connected, via a resistor 150 (having a resistance of approximately 20Ω), to the gate electrode of the FET 128. The gate electrode of the FET 128 is also connected, via a resistor 152 (having a resistance of approximately 22KΩ), to the ground voltage rail 122.

Two resistors 154, 156 (having respective resistances of approximately 974KΩ and 5.36KΩ) are connected in series, via an intermediate node 158, between the output terminal 134 and the ground voltage rail 122. The current mode control IC 144 has its V_{FB} input (pin 2) connected to the node 158 via a resistor 160 (having a resistance of approximately 47KΩ). The current mode control IC 144 has its COMP output (pin 1) connected to its V_{FB} input (pin 2) via a series-connected resistor 162 (having a resistance of approximately 100KΩ) and capacitor 164 (having a capacitance of approximately 0.1μF). The current mode control IC 144 has its current sense input (pin 3) connected to the ground voltage rail 122 via a capacitor 166 (having a capacitance of approximately 470pF) and to the source electrode of the FET 128 via a resistor 168 (having a resistance of approximately 1KΩ).

The current mode control IC 144 has its V_{CC} input (pin 7) connected to the bridge rectifier output node 120 via a resistor 170 (having a resistance of approximately 240KΩ) and connected to the ground voltage rail 122 via a capacitor 172 (having a capacitance of approximately 100μF). The current mode control IC 144 has its GND input (pin 5) connected to the ground voltage rail 122.

The power supply output terminals 134 and 136 are connected to a half-bridge inverter 174, whose output is connected to a series-resonant tank circuit 176. The output of the tank circuit is connected, via a transformer 178, to the three fluorescent lamps which are connected in series. The composition and operation of ballast sub-components 174, 176 and 178 are well-known in the art and need not be further described herein. Such sub-components are described more fully in, for example, U.S. patent application no. 07/636,833, which is assigned to the same assignee as the present application, and the disclosure of which is hereby incorporated by reference.

In operation of the circuit of FIG. 1, with a voltage of 277V, 60Hz (as shown in FIG. 2) applied across the input terminals 108 and 110, the bridge 112 produces between the node 120 and the ground voltage rail 122 a unipolar, full-wave rectified, DC voltage having a frequency of 120Hz. When the FET 128 is enabled to conduct, substantially the whole of this unipolar DC voltage appears across the inductor 124, and causes current to flow through the inductor. When the FET 128 is disabled from conducting, this inductive current causes the voltage across the inductor to increase. This increased voltage is applied through the diode 132 to the output terminal 134. The increased voltage between the output terminals 134 and 136 charges the capacitor 137 which powers the inverter 174, the series-resonant tank circuit 176 and the transformer 178 to drive the three series-connected fluorescent lamps 102, 104, 106.

The switching between enablement and disablement of the FET 128 is controlled by the control signal (output from pin 6) of the current mode control IC 144. The IC's control signal output is in the form of a pulse-width modulated signal, during whose mark intervals the FET is switched ON to enable conduction of current and during whose space intervals the FET is switched OFF to disable conduction of current. The IC's pulse-width modulated control signal at pin 6 has a nominal mark/space ratio of unity, producing a nominal 50% duty cycle. The frequency of the IC's pulse-width modulated control signal and the voltage at the node 120 determine the current drawn from the supply line.

In the circuit 100 the nominal frequency of the PWM control signal produced at pin 6 of the IC 144, which is determined by the product of the values of the resistor 146 and the capacitor 142, is approximately 23KHz.

However, by applying the 120Hz unipolar waveform output from the bridge 112 through the resistor 138 to the input at pin 4 of the current mode control IC 144, the frequency of the pulse-width modulated control signal produced at pin 6 of the IC is forced to vary in response to the AC line voltage (whose waveform is shown in FIG. 2) applied across the input terminals 108 and 110. As the instantaneous value of the unipolar bridge output voltage increases, the current applied to pin 4 of the IC 144 increases and causes the frequency of the PWM control signal output at pin 6 of the IC to increase. Thus the frequency of the PWM control signal output at pin 6 of the IC has its minimum, nominal value of approximately 23KHz when the bridge output voltage has its minimum, zero value, and the frequency of the PWM control signal output at pin 6 of the IC has its maximum value of approximately 43KHz when the bridge output voltage has its peak value. At intermediate values of the bridge output voltage the frequency of the IC's PWM control signal is proportionately reduced.

The frequency of the pulse-width modulated control signal produced at pin 6 of the IC 144 determines the current drawn from the bridge 112 and hence from the AC supply line. By forcing the line current (whose waveform is shown in FIG. 3) to vary in accordance with the applied line voltage in this way, the line current is forced to become sinusoidal, endowing the circuit 100 with a near-unity power factor and low harmonic distortion.

As referred to above, the line current is caused to vary in this way by the connection provided between the node 120 and the node 140 by the resistor 138, which causes a modulating signal from the output of the rectifier bridge 112 to be applied to the frequency determining input R_T/C_T at pin 4 of the IC 144. If the resistor 138 were removed, the frequency of the PWM output signal produced at pin 6 of the IC 144 would remain constant at approximately 23KHz, and the line current drawn by the circuit would be of the form shown in FIG. 4.

As can be seen from comparing the waveforms of FIG. 3 and 4, the waveform of FIG. 4 is noticeably less sinusoidal than that of FIG. 3, particularly in the regions marked 180 around the zero-crossings of the waveform. These deviations from sinusoidal shape in the waveform of FIG. 4 would manifest themselves as increased THD and decreased power factor, both of which are substantially avoided in the circuit 100 whose line current waveform is shown in FIG. 3.

Calculations and measurements have shown that the power factor and THD figure associated with the waveform of FIG. 4 are approximately 0.95 and 15% respectively, whereas the power factor and THD figure produced by the circuit 100 are approximately 0.99 and 5% respectively.

It will be appreciated the degree of modulation provided of the PWM output signal of the IC 144 could be varied by varying the value of the resistor 138 and additionally or alternatively by inserting a resistor (not shown) in parallel with the capacitor 142 between the node 140 and ground voltage rail. Such variation could be used to provide greater or lesser compensation for the non-sinusoidal regions 180 shown in FIG. 4, as desired.

It will also be appreciated that although the invention has been described above with respect to a power supply employing a boost inductor and incorporated in a ballast circuit for driving fluorescent lamps, the invention may be advantageously used in other types of power supplies for use in any application where THD and power factor are significant factors in power supply performance.

It will also be appreciated that various other modifications or alternatives to the above described embodiment will be apparent to the person skilled in the art without departing from the inventive concept of providing modulation, in accordance with an applied supply voltage, of a control signal which determines the line current drawn by a power supply, thereby reducing harmonic distortion and increasing power factor.

Claims

1. A power supply comprising:
an input for receiving an alternating supply voltage;
an output for producing a voltage derived from the supply voltage;
voltage producing means coupled between the input and the output for carrying a current and for producing a voltage therefrom;
switch means for controlling the current carried by the voltage producing means; and
control signal generating means for producing a pulsed control signal to control the switch means so as to control the current carried by the voltage producing means and thereby control the voltage produced thereby,
the improvement comprising modulating means coupled between the input and the control signal generating means for modulating the frequency of the control signal in accordance with the alternating supply voltage whereby the frequency of the control signal has a maximum value when the magnitude of the alternating supply voltage is a maximum so as to cause the current carried by the voltage producing means to have a waveform which approximates to that of the alternating supply voltage.

2. A power supply according to claim 1 wherein the voltage producing means comprises an inductance.

3. A power supply according to claim 1 or 2 wherein the switch means comprises a field effect transistor.

4. A power supply according to claim 1, 2 or 3 wherein the control signal is a pulse-width modulated signal.

5. A power supply according to any preceding claim wherein the control signal generating means comprises a current-mode control integrated circuit.

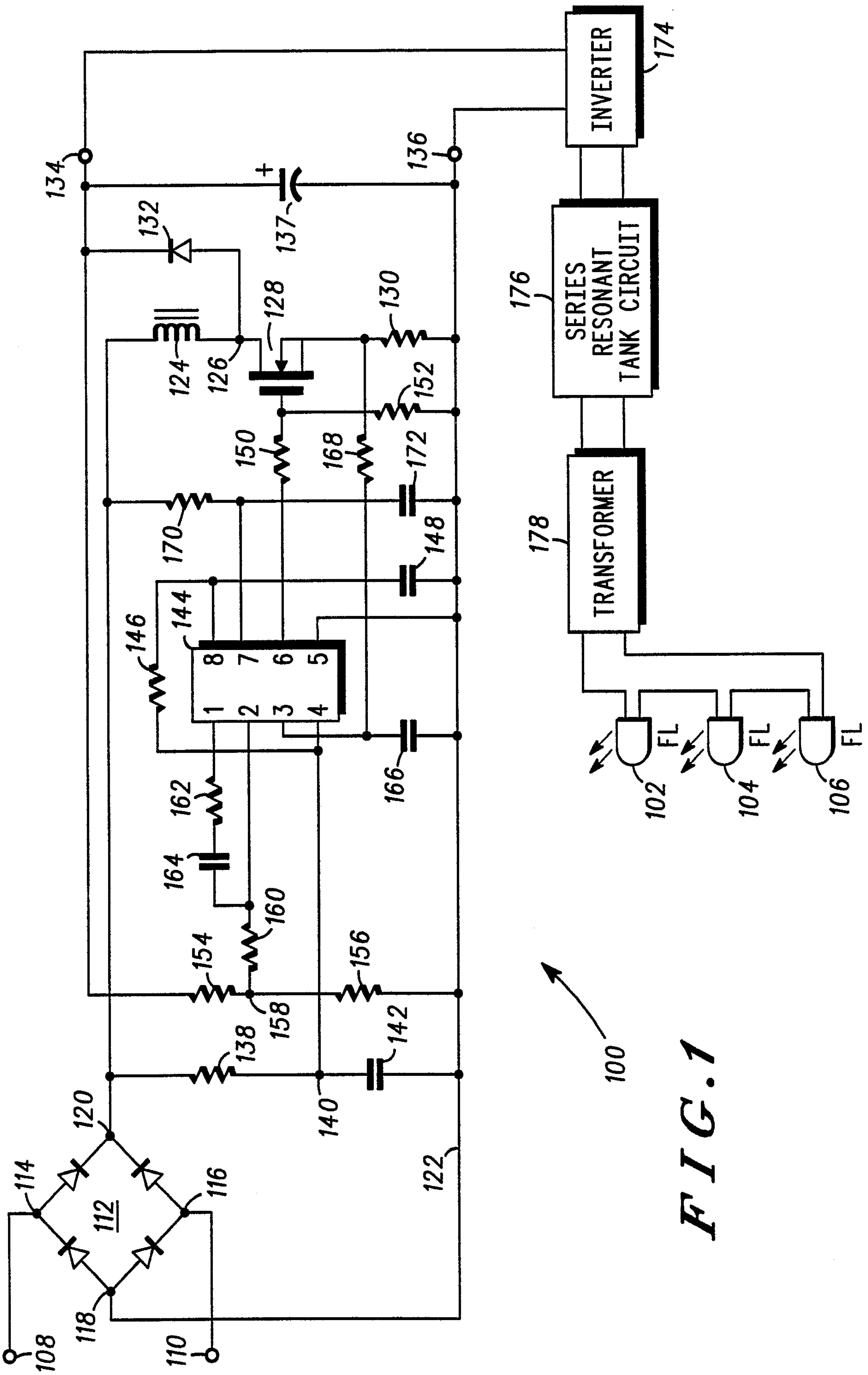
6. A power supply according to any preceding claim wherein the modulating means comprises an impedance coupled between the input and the control signal generating means.

7. A power supply for converting an AC voltage into a DC voltage, said power supply having a full wave rectifier coupled to said AC voltage, means for producing a pulse width modulated signal, said means having a control input, and means controlled by said signal for producing said DC voltage, the improvement comprising:
means for coupling said control input to the full wave rectifier to cause the frequency of said pulse width modulated signal to vary in accordance with the magnitude of said AC voltage whereby the frequency of said pulse width modulated signal has a maximum value when the magnitude of said AC voltage is a maximum, thereby obtaining high power factor and low harmonic distortion.

8. A power supply as set forth in claim 7 wherein said means for producing said pulse width modulated signal is powered from said full wave rectifier.

9. A power supply as set forth in claim 7 or 8 wherein said means for producing said DC signal comprises a voltage boost circuit.

10. A ballast for driving gas discharge lamps and incorporating a power supply according to any preceding claim.


INVERTER
174
SERIES RESONANT TANK CIRCUIT
176
TRANSFORMER
178
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F I G. 1

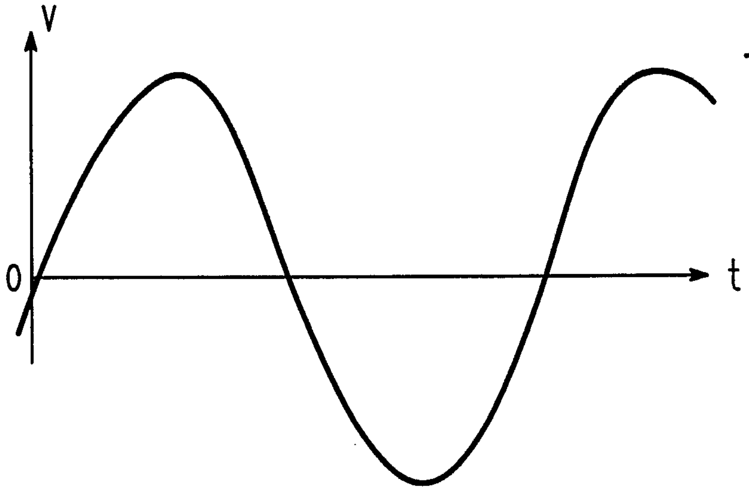

FIG. 2

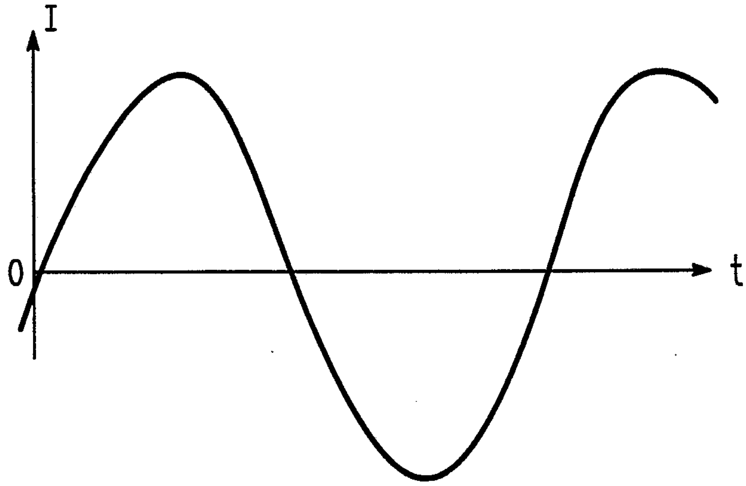

FIG. 3

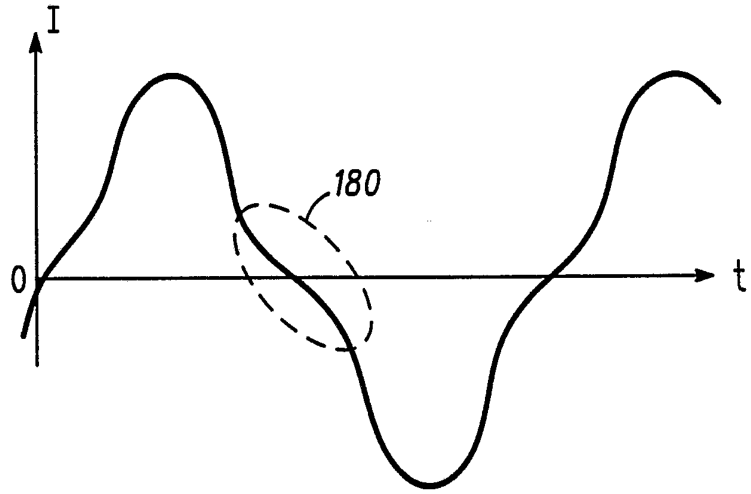

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 92/01752

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[5]: H 05 B 37/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[5]	H 05 B 41/00, H 05 B 37/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	EP, A2, 0 380 033 (SIEMENS) 01 August 1990 (01.08.90), see abstract; fig. 1. --	1,7
A	EP, A1, 0 352 983 (ASTEC) 31 January 1990 (31.01.90), see abstract; fig. 1. --	1,7
A	US, A, 4 920 302 (KONOPKA) 24 April 1990 (24.04.90), see abstract; fig. 1,2. --	1,7
A	US, A, 4 677 366 (WILKINSON) 30 June 1987 (30.06.87), see abstract; fig. 1,8. --	1,7
A	US, A, 4 870 327 (JORGENSEN) 26 September 1989	1,7

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
15 July 1992	13.08.92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	VAKIL

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages	Relevant to Claim No.
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zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

to the International Search Report to the International Patent Application No.

au rapport de recherche international relatif à la demande de brevet international n°

PCT/US 92/01752 SAE 58536

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

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Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
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