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**IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION**

OLE K. NILSSEN and
GEO FOUNDATION, LTD.,

Plaintiffs,

vs.

GENLYTE THOMAS GROUP, LLC.,
LIGHTECH ELECTRONIC
INDUSTRIES, LTD., and
LIGHTECH ELECTRONICS NORTH
AMERICA, INC.,

Defendants.

GENLYTE THOMAS GROUP, LLC.

Counter-Plaintiff,

vs.

OLE K. NILSSEN and
GEO FOUNDATION, LTD.,

Counter-Defendants.

No. 04 C 4689

Judge James B. Zagel

Magistrate Sidney I. Schenkier

FILED
MAY 17 2005 rQ
MICHAEL W. DOBBINS
CLERK, U.S. DISTRICT COURT

FIRST AMENDED COMPLAINT

Pursuant to this Court's order of April 28, 2005 granting leave to file an amended complaint, Plaintiffs, Ole K. Nilssen ("Nilssen") and Geo Foundation, Ltd. ("Geo Foundation"), by their undersigned attorneys, hereby complain of Defendants Genlyte Thomas Group LLC, Lightech Electronic Industries, Ltd., and Lightech Electronics North America, Inc. (collectively "Defendants") and allege as follows:

1. This Complaint comprises a single count for patent infringement.

A. Jurisdiction and Venue

2. Jurisdiction arises under 28 U.S.C. §1331 and §1338(a).

3. Venue in this Court is proper pursuant to 28 U.S.C. §1391 and §1400(b).

B. The Parties

4. Plaintiff, Ole K. Nilssen, maintains residences in Illinois and Florida. Nilssen conducts essentially all of his business activities in Illinois.

5. Plaintiff, Geo Foundation, is a not-for-profit corporation incorporated in the Cayman Islands, British West Indies.

6. Defendant Genlyte Thomas Group LLC ("Genlyte") is a Delaware corporation with its principal place of business in Louisville, Kentucky.

7. On information and belief Defendant Lightech Electronic Industries, Ltd., ("Lightech Israel") is a foreign corporation with its principal place of business in Israel.

8. Defendant Lightech Electronics North America, Inc. ("Lightech America") is a Delaware corporation with its principal place of business 5100 W. Kennedy Blvd., Ste. 185, Tampa, Florida 33609. Defendants Lightech Israel and Lightech America are collectively referred to as "Lightech Defendants".

9. Genlyte has been, and is currently, in the business of making and selling track lighting power supplies and/or track lighting systems. Genlyte sells track lighting power supplies and/or track lighting systems products throughout the United States through multiple divisions, including locations within the Northern District of Illinois.

10. Genlyte's sale and offer for sale of track lighting power supplies and/or track lighting systems within the Northern District of Illinois shows continuous and systematic contacts by Genlyte within the Northern District of Illinois.

11. In addition, Genlyte's selling and offering for sale track lighting power supplies and/or track lighting systems within the Northern District of Illinois establish minimum contacts. Genlyte made these contacts purposely to avail itself of the privilege of doing business within the Northern District of Illinois.

12. Genlyte's selling and offering for sale track lighting power supplies and/or track lighting systems within the Northern District of Illinois gives rise to and is related to Plaintiffs' cause of action for patent infringement.

13. On information and belief, the Lightech Defendants have been, and are currently, in the business of making and selling track lighting power supplies for track lighting systems. On information and belief, the Lightech Defendants sell track lighting power supplies throughout the United States. On information and belief, the Lightech Defendants' customers, including Defendant Genlyte, sell Lightech Defendants' track lighting power supplies and/or track lighting systems containing such track lighting power supplies throughout the United States, including locations within the Northern District of Illinois, and it is these sales which give rise to this cause of action.

14. Exercising jurisdiction over Defendants in the Northern District of Illinois is consistent with traditional notions of fair play and substantial justice.

C. Count I for Patent Infringement

15. Ole K. Nilssen is in the business of identifying, formulating plans for developing know-how and technology for, and implementing (via license agreements) promising new business technologies in the field of electronics, including track lighting power supplies and/or track lighting systems.

16. Nilssen is the inventor and owner of United States Patent Nos. 4,506,318; 5,036,253; 5,083,255; 5,144,202; 5,159,245 and 5,180,952 ("the patents-in-suit" or "patented inventions"), respectively attached hereto at Tabs 1-6.

17. Geo Foundation has been an exclusive licensee of the patents-in-suit since January 1, 2000, with an exclusive right to license others.

18. Geo Foundation, Ltd. has authorized Nilssen to negotiate patent license agreements on its behalf as a prospective licensor of the patents-in-suit and Nilssen has negotiated on behalf of Geo Foundation, Ltd.

19. The track lighting power supplies and/or track lighting systems that Defendants import, manufacture, use, and/or sell infringe on each of the six above-identified patents.

20. On information and belief, Defendants have had knowledge of these patents since sometime after their issuance and has knowingly and without justification infringed on these patents.

21. Plaintiffs have the right to bring suit with respect to the patents-in-suit.

22. Defendants have imported, made, used, and/or sold and continue to import, make, use and/or sell track lighting power supplies and/or track lighting systems embodying the inventions claimed in each of the patents-in-suit and will continue to do so unless enjoined by this Court.

23. On information and belief, Defendants have willfully infringed and continue to willfully infringe each of the patents-in-suit.

24. In the United States, purchasers of track lighting power supplies and/or track lighting systems imported, made and/or sold by Defendants have used in the past and continue to use such track lighting power supplies and/or track lighting systems in combination with other components, including power sources and lamps, thereby infringing one or more of the patents-in-suit.

25. On information and belief, each track lighting power supply and/or track lighting system imported, made, and/or sold by Defendants was designed to be used in connection with a power source and one or more lamps.

26. On information and belief, Defendants knew of one or more of the patents-in-suit when selling track lighting power supplies and/or track lighting systems to said purchasers.

27. Defendants have imported, manufactured, used, offered for sale, and/or sold track lighting power supplies and/or track lighting systems that constitute a material component of one or more of the patents-in-suit and which have no substantial use other than as an infringement of the patents-in-suit, and Defendants continue to do so.

28. On information and belief, Defendants knew and intended that purchasers of their track lighting power supplies and/or track lighting systems use the track lighting power supplies and/or track lighting systems in combination with other components, including power sources and lamps, so as to infringe one or more of the patents-in-suit.

29. On information and belief, Defendants have actively induced purchasers of their track lighting power supplies and/or track lighting systems to use the track lighting power supplies and/or track lighting systems in combination with other components, including power sources and lamps, so as to infringe each of the patents-in-suit.

WHEREFORE, Plaintiffs pray that judgment be entered against each Defendant:

(a) awarding damages and prejudgment interest to Plaintiffs under 35 U.S.C. §284;

(b) preliminarily and permanently enjoining Defendants from importing, making, using or selling track lighting power supplies and/or track lighting systems embodying the patented inventions;

(c) preliminarily and permanently enjoining Defendants from contributorily infringing and inducing the infringement of the patented inventions;

(d) increasing Plaintiffs' actual damages under 25 U.S.C. §284;

(e) awarding Plaintiffs reasonable attorney fees under 35 U.S.C. §285; and

(f) awarding such other relief as the Court deems proper.

Respectfully submitted,

Date: May 17, 2005

Raymond N. Nimrod
John E. Titus
Jonathan Hill
Stephen M. Geissler
JENNER & BLOCK LLP
One IBM Plaza
Chicago, Illinois 60611
(312) 222-9350

Attorney for Plaintiffs
Ole K. Nilssen
Geo Foundation Ltd.

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United States Patent [19]

Nilssen

[11] **Patent Number:** **4,506,318**

[45] **Date of Patent:** **Mar. 19, 1985**

[54] **INVERTER WITH CONTROLLABLE RMS OUTPUT VOLTAGE MAGNITUDE**

[76] Inventor: **Ole K. Nilssen**, Caesar Dr., Rte. 5, Barrington, Ill. 60010

[21] Appl. No.: **487,817**

[22] Filed: **Apr. 22, 1983**

[51] **Int. Cl.**^{3} **H02M 7/44**

[52] **U.S. Cl.** **363/132**; 363/98

[58] **Field of Search** 363/17, 22, 23, 34, 363/37, 38, 131, 132, 157, 159, 163, 164, 165, 98

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,968,738	1/1961	Pintell	363/23 X
3,267,349	8/1966	Krause	363/22 X
4,017,785	4/1977	Perper	363/37

FOREIGN PATENT DOCUMENTS

2712941	9/1978	Fed. Rep. of Germany	363/34

Primary Examiner—Peter S. Wong
Assistant Examiner—Judson H. Jones

[57] **ABSTRACT**

An inverter is adapted to be powered from full-wave-rectified unfiltered 60 Hz power line voltage and to provide an amplitude-modulated output of relatively high-frequency voltage. The inverter has to be triggered into oscillation. However, once triggered, it will continue to oscillate—but only for as long as its DC supply voltage is present.

Since the DC supply voltage falls to zero magnitude once for each half-cycle of the 60 Hz power line voltage, the inverter stops oscillating after each such half-cycle; and therefore, for as long as output voltage is desired, the inverter has to be re-triggered after each half-cycle.

Triggering is accomplished by a Diac in combination with an RC integrating circuit; which means that the inverter is triggered into oscillation some time period after the onset of each half-cycle. The length of this time period is determined by the nature of the RC integrating circuit, in the same way as phase-control is accomplished in an ordinary Triac-type incandescent lamp dimmer.

By varying the time-constant of the RC integrating circuit, the inverter can be triggered into oscillation with varying amounts of delay; which means that the net effective RMS magnitude of the output voltage can be adjusted by adjusting the time-constant of the RC integrating circuit.

8 Claims, 3 Drawing Figures

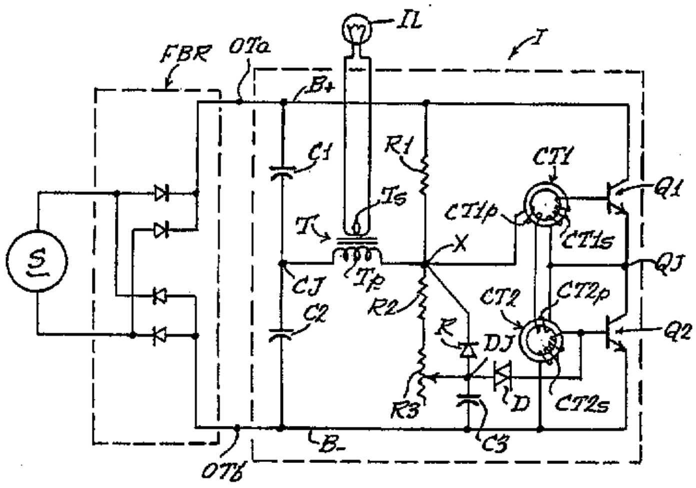

Fig. 1.

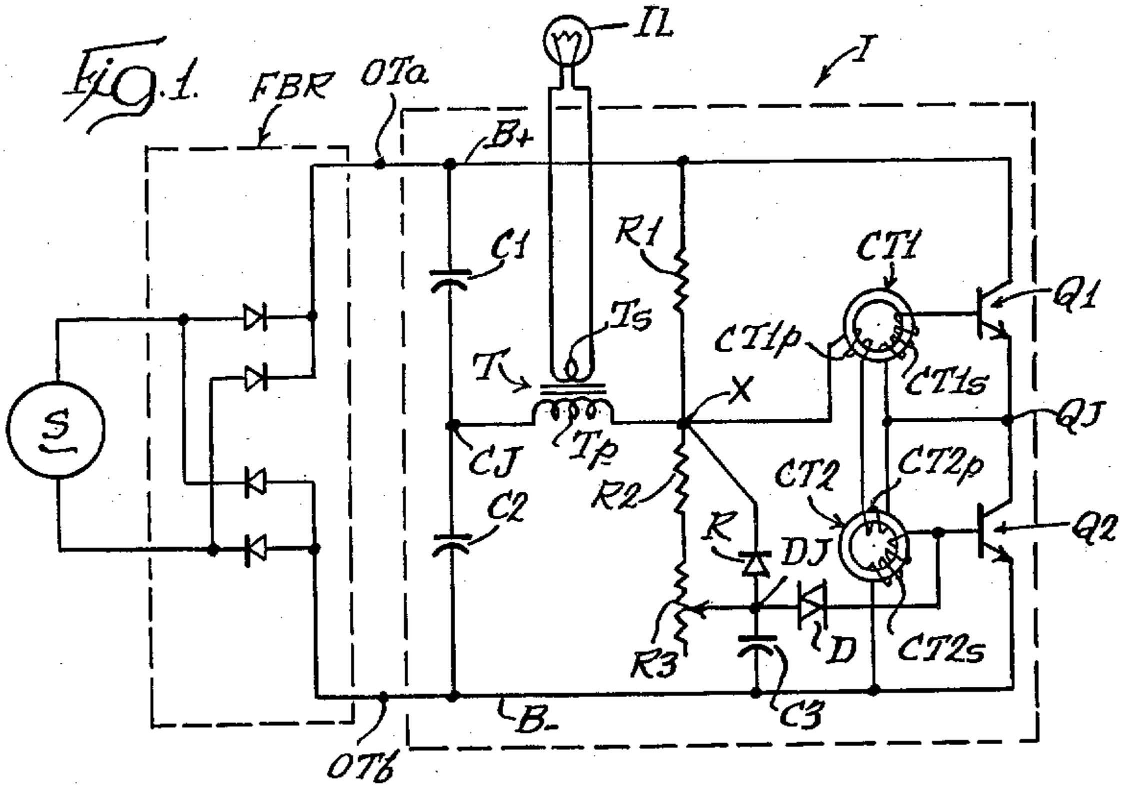
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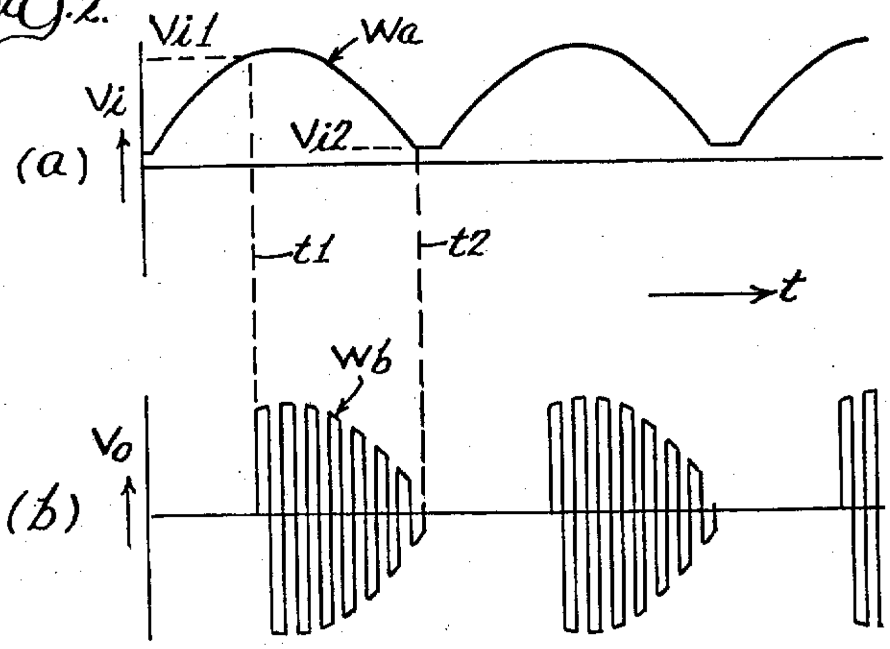
Fig. 2.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INVERTER WITH CONTROLLABLE RMS OUTPUT VOLTAGE MAGNITUDE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to power-line-operated inverter-type power supplies with means for controllably adjusting the RMS magnitude of the inverter output voltage.

2. Description of Prior Art

Power-line-operated inverter-type power supplies are presently being used in a variety of applications. In particular, such power supplies are frequently being used for powering low-voltage incandescent lamps or similar loads.

When using such inverter-type power supplies in connection with powering low-voltage incandescent lamps, it is sometimes desirable to be able controllably to adjust the RMS magnitude of the output voltage, thereby providing for adjustment of the amount of light provided by the lamps. However, to provide cost-effectively for means to effect controllable adjustment of the RMS magnitude of the output of such power supplies is not as simple as it might initially appear.

Of course, to achieve such adjustment control, one might use a variable-ratio transformer (Variac) between the power line and the input of the power supply. However, the cost and complexities associated with such an approach is unacceptably high in most applications.

Or, one might consider the use of a Triac-type voltage control means mounted between the power line and the power supply. However, Triac-type voltage control means simply do not function properly with the kind of input characteristics normally associated with power-line-operated inverter-type power supplies.

Then there is the possibility of using an inverter-type power supply with a special input circuit that would permit the use of a Triac-type control means; which input circuit would then have to make the inverter power-input-characteristics appear substantially like a resistive load. Even so, however, there is the cost of the Triac-type control to consider.

The present invention represents yet another solution; which other solution is novel and substantially more cost-effective than that of using a Triac-type control means between the power line and the inverter input.

SUMMARY OF THE INVENTION

Objects of the Invention

An object of the present invention is that of providing a power-line-operated inverter-type power supply with cost-effective means to permit controllable adjustment of the RMS magnitude of its output voltage.

This as well as other objects, features and advantages of the present invention will become apparent from the following description and claims.

Brief Description

In its preferred embodiment, subject invention is a power supply adapted to be powered from the regular 60 Hz power line voltage and to provide an output of relatively high-frequency (30 kHz) substantially squarewave voltage. This output voltage is provided by an inverter that is powered by way of a pulsed DC supply voltage derived from unfiltered rectification of the power line voltage. Thus, the high-frequency inverter output voltage is pulse-amplitude-modulated in correspondence with the pulse-amplitude-modulations of the pulsed DC supply voltage.

The inverter is of a type that has to be triggered into oscillation. However, once triggered, it will continue to oscillate by itself—but only for as long as its DC supply voltage is above a certain minimal magnitude.

Since the pulsed DC supply voltage falls to zero magnitude between each pulse, the inverter stops oscillating between each pulse. Thus, as long as output voltage is desired, the inverter has to be triggered after each pulse of the DC supply voltage.

Inverter triggering is accomplished by a Diac in combination with an RC integrating circuit; which means that—upon each application of a pulse of DC supply voltage—the inverter is triggered into oscillation only after the DC supply voltage has been present for some period of time; the length of this period being determined by the nature of the RC integrating circuit, much in the same way as phase-control is accomplished in an ordinary Triac-type incandescent lamp dimmer.

By varying the time-constant of the RC integrating circuit, the inverter can be made to be triggered into oscillation with varying amounts of delay; which means that the net effective RMS magnitude of the output voltage can be adjusted by adjusting the time-constant of the RC integrating circuit.

Thus, the RMS magnitude of the output of the power supply can be controlled much in the same fashion as can the RMS output voltage of an ordinary Triac-type voltage control means.

More particularly, in its preferred embodiment, this power-line-operated inverter-type power supply comprises the following key elements:

(a) A full-wave rectifier means connected in circuit with a regular 120-Volt/60-Hz power line and adapted to provide an unfiltered DC supply voltage, said DC supply voltage being unidirectional and having an instantaneous magnitude that is substantially equal to the absolute value of the instantaneous magnitude of the sinusoidal voltage on the power line;

(b) A self-oscillating inverter connected with and powered by said DC supply voltage, said inverter being of a type that needs to be triggered into oscillation, but which ceases to oscillate once the instantaneous magnitude of said DC supply voltage falls below a certain minimal level, said inverter being operative to convert said DC supply voltage into a substantially squarewave output voltage of about 30 kHz frequency, the absolute value of the instantaneous magnitude of said squarewave output voltage being substantially proportional to the instantaneous magnitude of said DC supply voltage;

(c) Means for triggering said inverter into oscillation some time-period after the instantaneous magnitude of the DC supply voltage exceeds a certain threshold level, the length of said time-period being on the order of a fraction of the half-period of said power line voltage, the magnitude associated with said minimal level being smaller than the magnitude associated with said threshold level;

(d) Load means connected with and powered by said squarewave output voltage; and

(e) Means for controllably adjusting the length of said time period; whereby:

the squarewave voltage provided to said load means has an instantaneous absolute magnitude that is substantially proportional to the instantaneous absolute magnitude of the voltage on the power line, except for an adjustable time-interval between each half-cycle of the power line voltage, during which adjustable time-interval the magnitude of said squarewave voltage is substantially zero, the length of said adjustable time-interval being somewhat larger than that of said time period;

thereby permitting controllable adjustment of the effective RMS magnitude of the squarewave output voltage, the integrating period for establishing said effective RMS magnitude being equal to or longer than said half-period.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates the preferred embodiment of the invention, showing an inverter-type power supply adapted to power a low-voltage incandescent lamp.

FIG. 2*a* illustrates the waveform of the DC supply voltage applied to the inverter; FIG. 2*b* illustrates the overall waveform of the inverter's amplitude-modulated squarewave output voltage.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Description of the Drawings

In FIG. 1, a source S of 120 Volt/60 Hz voltage is connected with full-bridge rectifier means FBR. Positive output terminal OTa of rectifier means FBR is connected directly with a B+ bus; and negative output terminal OTb of rectifier means FBR is connected directly with a B− bus.

Between the B+ bus and the B− bus is connected a series-combination of two capacitors C1 and C2, which two capacitors are connected together at a junction CJ.

Between the B+ bus and the B− bust is also connected a series-combination of two transistors Q1 and Q2.

The secondary winding CT1*s* of positive feedback current transformer CT1 is connected directly between the base and the emitter of transistor Q1; and the secondary winding CT2*s* of positive feedback current transformer CT2 is connected directly between the base and the emitter of transistor Q2.

The collector of transistor Q1 is connected directly with the B+ bus; the emitter of transistor Q2 is connected directly with the B− bus; and the emitter of transistor Q1 is connected directly with the collector of transistor Q2, thereby forming junction QJ.

The series-connected primary windings CT1*p* and CT2*p* are connected directly between junction QJ and a point X; while the primary winding Tp of transformer T is connected between point X and junction CJ.

Transformer T has a secondary winding Ts, which is connected directly with an incandescent lamp IL.

A resistor R1 is connected with its one terminal to the B+ bus and with its other terminal to point X. Another resistor R2 is connected between point X and one terminal of a variable resistor R3. The other terminal of R3 is connected to junction DJ, to which junction is also connected one of the terminals of a capacitor C3. The other terminal of C3 is connected to the B− bus.

A Diac D is connected between junction DJ and the base of transistor Q2.

A rectifier R is connected with its anode to junction DJ and with its cathode to junction QJ.

The overall inverter is identified with the letter I.

Actual values and descriptions of the critical components of the preferred arrangement in FIG. 1 are listed as follows.

Output of Source S:	120 Volt/60 Hz;
Full Bridge Rectifier FBR:	Four 1N4004's;
Capacitors C1 & C2:	0.47 μF/200 Volt;
Transistors Q1 & Q2:	Motorola MJE13002's;
Resistor R1:	33 kOhm/0.25 Watt;
Resistor R2:	100 kOhm/0.25 Watt;
Adjustable Resistor R3:	1.5 MegOhm Potentiometer;
Capacitor C3	22 nF/50 Volt;
Rectifier R:	1N4004;
Diac D:	General Electric ST-2;
Transformers CT1 & CT2:	Wound on Ferroxcube Toroids 213T050 of 3E2A Ferrite Material with two turns of #27 wire for the primary windings and ten turns of #31 wire for the secondary windings;
Transformer T:	Wound on a Ferroxcube 2616 Pot Core of 3C8 Ferrite Material with 95 turns of #27 wire for the primary winding and 20 turns of five twisted strands of #27 wire for the secondary winding;
Incandescent Lamp IL:	12 Volt/25 Watt.

The frequency of inverter oscillation associated with the component values identified above is approximately 30 kHz.

In FIG. 2*a*, the waveform identified as Wa represents the voltage Vi present between the B− bus and the B+ bus as plotted against time t. The magnitude of voltage Vi at the time t1 when the inverter is triggered into oscillation is indicated as Vi1. The magnitude of voltage Vi at the time t2 the inverter drops out of oscillation is indicated as Vi2.

In FIG. 2*b*, the waveform identified as Wb represents the inverter output voltage Vo plotted against time t; which output voltage exists across the secondary winding Ts of transformer T in FIG. 1, and which is the voltage provided to incandescent lamp IL.

Description of Operation

The operation of the circuit arrangement of FIG. 1 is described as follows.

Source S represents an ordinary 12 Volt/60 Hz electric utility power line, the voltage from which is rectified in full-wave fashion by full-bridge rectifier means FBR. Thus, in the absence of filtering means, the voltage present across output terminals OTa and OTb is substantially as depicted in FIG. 2*a*; which voltage is applied directly to the inverter circuit I.

This inverter circuit, which consists of the two series-connected switching transistors Q1 and Q2 in combination with the two positive feedback transformers CT1 and CT2, represents a self-oscillating half-bridge inverter and operates in a manner that is analogous with circuits previously described in published literature, as for instance in U.S. Pat. No. 4,184,128 entitled High Efficiency Push-Pull Inverters.

Since the DC voltage-supply feeding the inverter has no filtering capacitors, it is necessary to provide within the inverter a low impedance return path for the inverter current. Such a low impedance return path is provided by way of the two series-connected capacitors C1 and C2. However, it is necessary that the capacitance values of these capacitors be kept small enough not to represent significant energy-storing capacity in comparison to the amount of energy being drawn by the inverter over a half-cycle of the power line voltage. In this case, with the power drawn being about 25 Watt (which is about 208 milli-Joule per half-cycle of the 60 Hz power line voltage) the energy stored by the two series-connected 0.47 uF capacitors is indeed small in comparison (being only 2.6 milli-Joule at 150 Volt).

In the inverter circuit of FIG. 1, the bases of the transistors are—in terms of DC—shorted to their emitters; which implies that the inverter can not start oscillating by itself. However, by providing but a single brief pulse to the base of transistor Q2, this transistor is caused to conduct momentarily; which momentary conduction puts this one transistor into an amplifying situation; which is enough to trigger the inverter into oscillation—provided, of course, that there is adequate voltage present between the B− bus and the B+ bus.

Once triggered into oscillation, the inverter will continue to oscillate until the voltage between the B− bus and the B+ bus falls to such a low level as to be inadequate for sustaining regenerative feedback. At this point, which is identified as Vi2 in FIG. 2*a*, oscillations cease.

Inverter triggering is accomplished by way of a Diac; which Diac itself is triggered by the voltage on capacitor C3.

The output of the half-bridge inverter circuit is a substantially squarewave 30 kHz AC voltage, which output is provided between point X and junction CJ, and across which output is connected the primary winding of transformer T. The peak-to-peak amplitude of this squarewave voltage is equal to the magnitude of the DC voltage present between the B− bus and the B+ bus; and therefore, as the magnitude of this DC voltage varies, so does the amplitude of the squarewave output voltage.

The incandescent lamp IL is connected directly across the secondary winding Ts of transformer T; which means that the voltage presented to the incandescent lamp is directly proportional to the inverter circuit output voltage.

Being supplied with a pulsed DC voltage similar to that depicted in FIG. 2*a*, the inverter circuit—even if oscillating at some given moment—will cease oscillating when the DC supply voltage falls below a certain minimal level (Vi2 in FIG. 2*a*). Thus, if the inverter is triggered into oscillation at some time during each of the unidirectional sinusoidally-shaped voltage pulses constituting the DC supply voltage, it will cease to oscillate at or near the end of each of these pulses.

Thus, the inverter circuit of FIG. 1 behaves much like a Triac: it can be triggered ON, and will remain ON until the end of the power-cycle: until current flowing to the load falls below a certain minimal level. And, like a Triac, it can be triggered at substantially any point within the power-cycle; which means that it can be phase-controlled just like a Triac.

In other words, the RMS power provided to the incandescent lamp can be controlled over a wide range simply by controlling the timing of the inverter trigger point (t1 in FIG. 2).

Triggering of the inverter circuit is accomplished essentially the same way as is triggering of a Triac, and phase control is accomplished in the same manner.

In FIG. 1, resistor R2 and R3 in combination constitutes a resistance means through which capacitor C3 is charged. By adjusting the magnitude of the combined resistance, the time to charge capacitor C3 is similarly adjusted; which implies that the phase-point at which the inverter is triggered into oscillation is correspondingly adjusted.

The purpose of rectifier R is that of making sure that capacitor C3 gets fully discharged after the inverter is triggered into oscillation; which implies that this capacitor will start each new power cycle in a fully discharged condition, thereby assuring time-consistent triggering.

The reason for having R2 as a resistor physically separate from R3 is that of preventing the voltage at point X from being applied directly to capacitor C3, which could provide for a situation of actually preventing triggering from taking place.

The purpose of resistor R1, the resistance value of which is quite small in comparison with that of R2 and R3 combined, is that of making sure that there is enough voltage at junction CJ (relative to the B− bus) to permit the inverter circuit to be triggered into oscillation.

Otherwise, the following comments are offered.

(a) The concept of feeding an inverter with a pulsed DC voltage and to have its oscillations phase controlled (in relationship to the phasing of the DC pulses) is not limited to be used with a half-bridge inverter circuit. Most any type of self-oscillating inverter circuit may be used, the chief criterion being that the inverter circuit must be of such a nature as to have to be triggered into oscillation.

(b) To achieve a reasonably wide range of control of RMS output voltage, it is important that the inverter be capable of sustained self-oscillation even at relatively low levels of DC supply voltage. In the circuit of FIG. 1, stable inverter self-oscillation is sustained down to a DC supply voltage of about 20 Volt; below which voltage oscillations abruptly cease.

(c) By making the combined resistance of R2 and R3 large enough, it is readily possible to arrange for the inverter not to be triggered into oscillation at all during the duration of a given pulse of the DC supply voltage. However, it is important to recognize that—if the time-constant associated with C3 and the combined resistance of R2 and R3 is too large to permit triggering within a given pulse of the DC supply voltage—triggering may never-the-less take place at a later time, such as during the following pulse. Such delayed triggering is generally undesirable, but can be avoided simply by preventing R3 from reaching a resistance level high enough to cause it.

(d) By providing for means by which the inverter trigger circuit can be activated and/or de-activated (such as with a switch means connected between R2 and R3, and perhaps actuated by the same means as is used for adjusting the magnitude of R3), inverter ON-OFF control can be had in addition to phase-control.

It is believed that the present invention and its several attendant advantages and features will be understood from the preceeding description. However, without departing from the spirit of the invention, changes may be made in its form and in the construction and interrelationships of its component parts, the form herein presented merely representing the preferred embodiment.

I claim:

1. A power supply adapted to be powered from the relatively low frequency voltage on a regular electric utility power line and to provide a relatively high frequency output voltage, comprising:

rectifier means connected with said power line and operative to provide a DC supply voltage, said DC supply voltage being characterized by having an instantaneous undirectional magnitude that is substantially equal to the instantaneous absolute magnitude of said low frequency voltage, whereby said instantaneous unidirectional magnitude increases above a certain threshold level once for each half-cycle of said relatively low frequency voltage and decreases below said certain threshold level once for each half-cycle of said relatively low frequency voltage;

inverter connected with said DC supply voltage and operative to provide said relatively high frequency output voltage, said inverter characterized by: (i) ceasing operation each time the instantaneous magnitude of said DC supply voltage decreases below said certain threshold level, (ii) resuming operation each time after the magnitude of said DC supply voltage has increased above said certain threshold level, but only if it is provided with a trigger signal; and

trigger means connected in circuit with said DC supply voltage and operable to provide said trigger signal to said inverter some pre-selected time-period after each time the magnitude of said DC supply voltage has increased above said certain threshold level, the duration of said pre-selected time-period being less than that of the half-period of said relatively low frequency voltage,

whereby said inverter starts and stops operation once during each half-cycle of said relatively low frequency voltage, thereby correspondingly providing said output voltage for only a pre-selected fraction of the duration of each half-cycle of said relatively low frequency voltage.

2. The power supply of claim **1** combined with an adjustment means for adjusting the duration of said pre-selected time-period, resulting in a corresponding adjustment of said pre-selected fraction, thereby permitting the adjustment of the RMS magnitude of said output voltage.

3. The power supply of claim **2** wherein said adjustment means includes an adjustable resistance means.

4. A power supply adapted to be powered from the relatively low frequency line voltage on a regular electric power line and operative to provide a relatively high frequency output voltage, comprising:

rectifier means connected with said power line and operative to provide a non-filtered DC supply voltage;

inverter connected with said DC supply voltage and operative when oscillating to provide said output voltage, said inverter characterized by: (i) ceasing oscillation whenever the magnitude of said DC supply voltage decreases below a certain minimum level, and (ii) resuming oscillation only after the magnitude of said DC supply voltage has increased above said certain minimum level, but then only after having received a trigger pulse; and

trigger means connected in circuit with said inverter and operative to provide said trigger pulse a pre-selected brief time-period after the magnitude of said DC supply voltage has increased above said certain minimum level, said time-period being shorter than the period of said line voltage;

whereby said output voltage is periodically intermittent with a periodicity equal to that of said line voltage.

5. The power supply of claim **4** and adjustment means by which the duration of said pre-selected brief time-period may be adjusted, thereby permitting adjustment of the RMS magnitude of said output voltage.

6. The power supply of claim **4** and means for preventing a trigger pulse from being provided during any period when the inverter is oscillating.

7. A power supply adapted to be powered from the relatively low frequency line voltage on an ordinary electric power line and to provide a relatively high frequency output voltage, said power supply comprising:

rectifier means connected with said power line and operative to provide a non-filtered DC voltage, the magnitude of said DC voltage falling below and increasing above a certain threshold level at least once during each cycle of said line voltage;

inverter connected with said DC voltage and operative, when oscillating, to provide said output voltage, said inverter characterized by: (i) ceasing oscillation whenever the magnitude of said DC voltage falls below said threshold level, (ii) resuming its oscillation whenever the magnitude of said DC voltage has increased above said threshold level, but then only if provided with a trigger signal; and

trigger means for providing said trigger signal some pre-selected time-period after each time the magnitude of said DC voltage has increased above said threshold level;

whereby said output voltage is provided during only a fraction of the period of said line voltage.

8. The power supply of claim **7** wherein means have been provided for adjustment of the duration of said pre-selected time-period, thereby permitting adjustment of the RMS magnitude of said output voltage.

* * * * *

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United States Patent [19]

Nilssen

[11] **Patent Number: 5,036,253**

[45] **Date of Patent: Jul. 30, 1991**

[54] INVERTER POWER SUPPLY FOR INCANDESCENT LAMP

[76] Inventor: **Ole K. Nilssen**, Caesar Drive, Barrington, Ill. 60010

[21] Appl. No.: **461,653**

[22] Filed: **Jan. 8, 1990**

Related U.S. Application Data

[63] Continuation of Ser. No. 667,691, Nov. 2, 1984, which is a continuation-in-part of Ser. No. 487,817, Apr. 22, 1983, Pat. No. 4,506,318.

[51] **Int. Cl.**^{5} **H05B 41/00**

[52] **U.S. Cl.** **315/151**; 315/194; 315/224; 315/225; 315/362

[58] **Field of Search** .... 315/151, 194, 224, 225, 315/291, 311, 362, DIG. 4

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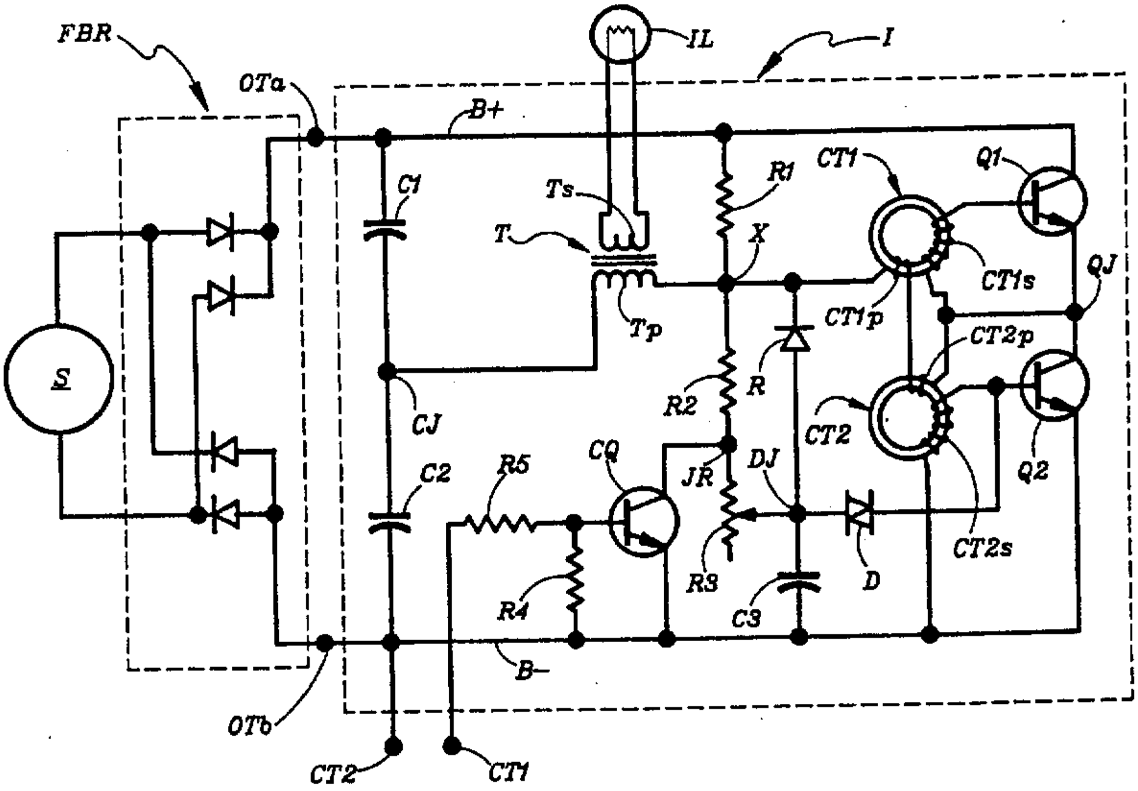
Primary Examiner—Robert J. Pascal

[57] **ABSTRACT**

An inverter is powered by a magnitude-modulated DC supply voltage derived by rectification from an ordinary 120Volt/60Hz electric utility power line. The inverter powers a low voltage (12 Volt) incandescent lamp with a magnitude-modulated high frequency (30 kHz) voltage. The magnitude modulation on the high frequency voltage is proportional to the magnitude modulation on the DC supply voltage.

16 Claims, 2 Drawing Sheets



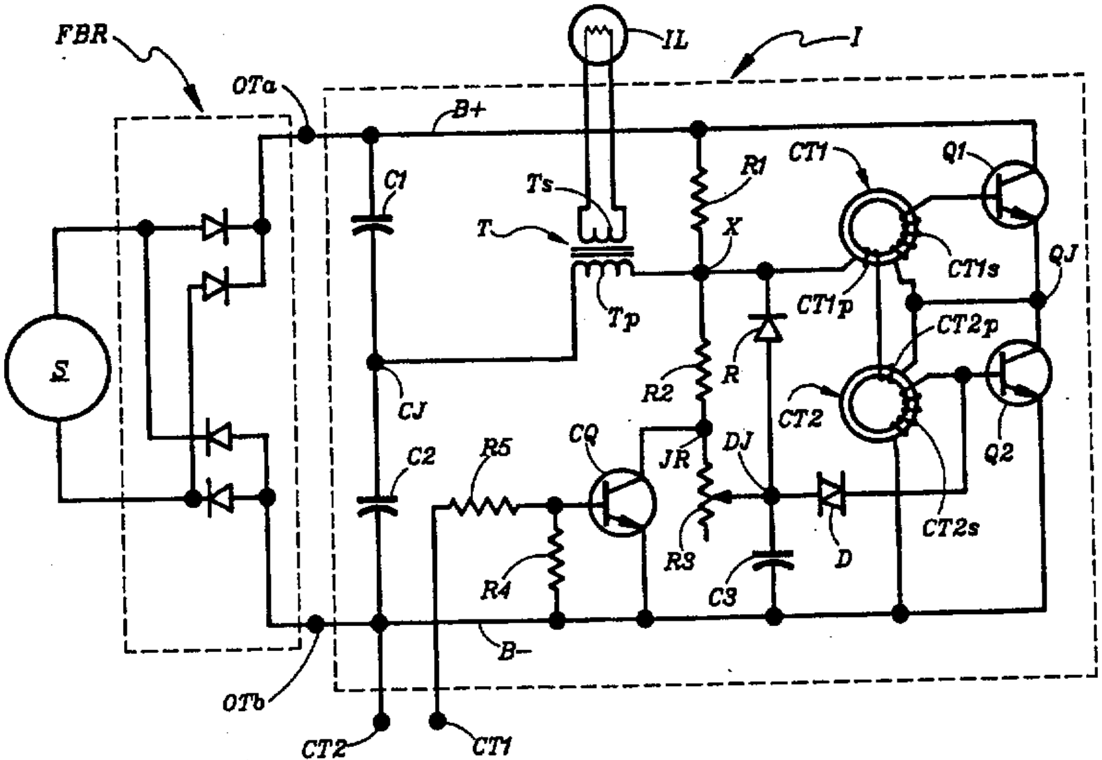

FBR
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Fig. 1

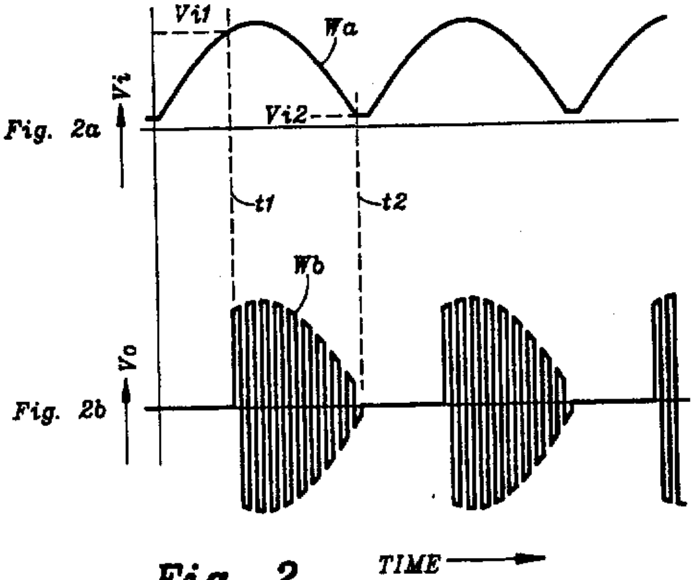
Vi1
Wa
Vi
Fig. 2a
Vi2
t1
t2
Wb
Vo
Fig. 2b
TIME

Fig. 2

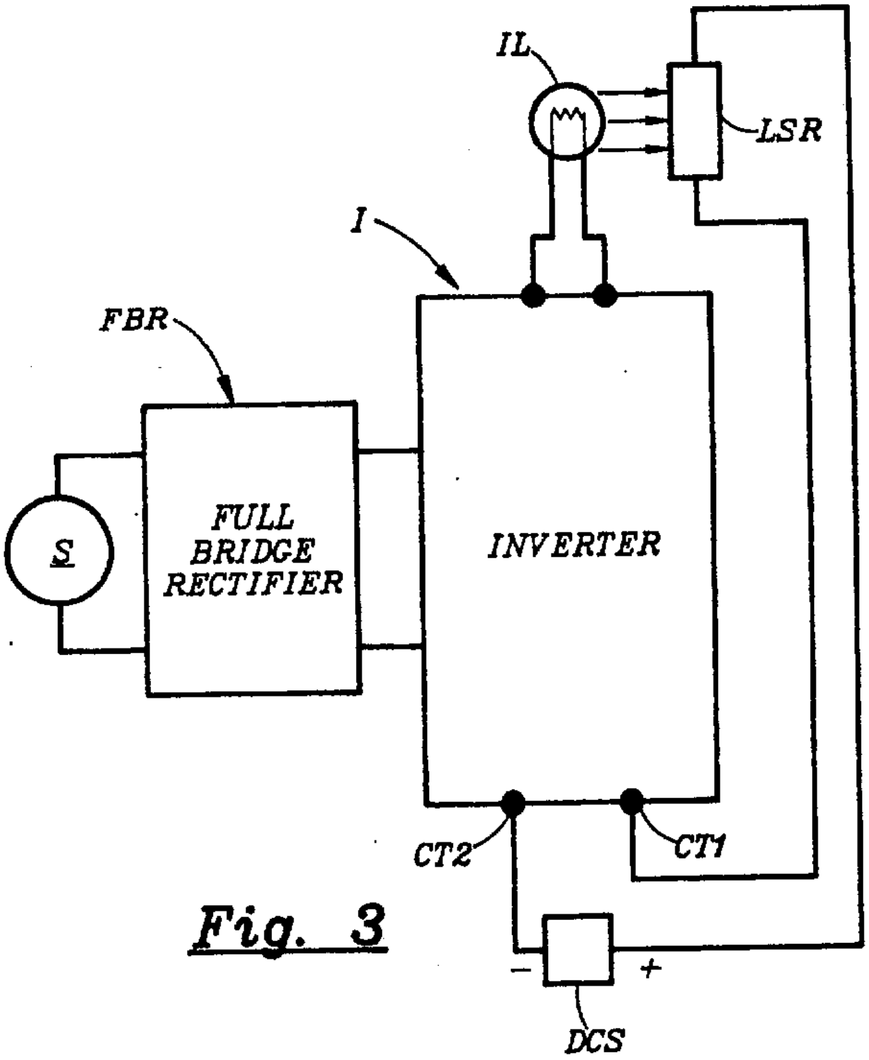

Fig. 3

INVERTER POWER SUPPLY FOR INCANDESCENT LAMP

CONTINUATION-IN-PART

This application is a Continuation of application Ser. No. 06/667,691 filed 11/02/84; which is a Continuation-in-Part of application Ser. No. 06/487,817 filed 04/22/83.

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to controllable power-line-operated inverter-type power supplies for incandescent lamps.

2. Description of Prior Art

Power-line-operated inverter-type power supplies are presently being used in a variety of applications. For instance, such power supplies are frequently being used for powering low-voltage incandescent lamps.

When using such inverter-type power supplies in connection with powering various loads, such as low-voltage incandescent lamps or microwave magnetrons, it is sometimes desirable to be able by way of electrically actuatable means to control the inverter output voltage, thereby providing for control of the power provided to the load. However, to provide cost-effectively for electrically actuatable means to effect control of the output of inverters is not as simple as it might initially appear.

Of course, to achieve such control, one might use an electrically actuatable variable-ratio transformer (Variac) between the power line and the input of the power supply. However, the cost and complexities associated with such an approach would be unacceptably high in most applications.

Or, one might consider the use of a Triac-type voltage control means mounted between the power line and the power supply. However, Triac-type voltage control means simply do not function properly with the kind of input characteristics normally associated with power-line-operated inverter-type power supplies.

Then, there is the possibility of using an inverter-type power supply with a special input circuit that would permit the use of a Triac-type control means; which input circuit would then have to make the inverter power-input-characteristics appear substantially like a resistive load. Even so, however, there is the cost and the electrical inefficiency of the Triac-type control to consider.

The present invention represents yet another solution; which other solution is novel, less costly and electrically more efficient than that of using a Triac-type control means between the power line and the inverter input.

SUMMARY OF THE INVENTION

Objects of Invention

An object of the present invention is that of providing a power-line-operated inverter-type power supply having electrically actuatable means to permit output voltage control.

This as well as other objects, features and advantages of the present invention will become apparent from the following description and claims.

Brief Description

In its preferred embodiment, subject invention is a power supply adapted to be powered from the regular 60 Hz power line voltage and to provide an output of relatively high-frequency (30 kHz) substantially square-wave voltage. This output voltage is provided by an inverter that is powered by way of the pulsed DC voltage derived from unfiltered full-wave rectification of the 60 Hz power line voltage. Thus, the high-frequency inverter output voltage is pulse-amplitude-modulated at a 120 Hz rate—in correspondence with the pulse-amplitude-modulations of the pulsed DC supply voltage.

The inverter is of a type that has to be triggered into oscillation. However, once triggered, it will continue to oscillate, but only for as long as the instantaneous magnitude of its pulsed DC supply voltage exceeds a certain threshold level.

Since the pulsed DC supply voltage falls to zero magnitude between each pulse, the inverter stops oscillating between each pulse. Thus, as long as output voltage is desired, the inverter has to be re-triggered after each pulse of the DC supply voltage.

Inverter triggering is accomplished by a Diac in combination with an RC integrating circuit; which means that—upon each application of a pulse of DC supply voltage—the inverter is triggered into oscillation only after the DC supply voltage has been present for some period of time; the length of this period being determined by the nature of the RC integrating circuit—much in the same way as phase-control is accomplished in an ordinary Triac-type incandescent lamp dimmer.

Connected with the RC integrating circuit is a control transistor, the effective impedance of which can be varied over a wide range by way of an electrical control voltage. With this control voltage having a relatively low magnitude, the inverter is triggered into oscillation quite early in the period of each pulse of the DC supply voltage; whereas, with this control voltage having a relatively large magnitude, no inverter triggering takes place at all.

For in-between magnitudes of the control voltage, inverter triggering takes place at substantially corresponding in-between delays relative to the onset of each DC pulse; which means that the net effective RMS magnitude of the output voltage can be adjusted by adjusting the magnitude of the control voltage.

Thus, by providing a control voltage to a pair of control terminals, the magnitude of the inverter output voltage can be adjusted over a wide range: from a maximum and all the way down to zero output—with a response time equal to half a cycle of the 60 Hz power line voltage.

By sensing the average or RMS magnitude of the inverter output voltage and by providing a control voltage to the control transistor that is effectively proportional to that average or RMS magnitude, output magnitude control can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates the preferred embodiment of the invention, showing an inverter-type power supply adapted to power a low-voltage incandescent lamp.

FIG. 2*a* illustrates the waveform of the DC supply voltage used for powering the inverter; and FIG. 2*b* illustrates the waveform of the inverter's squarewave output voltage.

FIG. 3 illustrates the circuit of FIG. 1 arranged with feedback means operative to automatically control the RMS magnitude of the inverter output voltage.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Description of the Drawings

In FIG. 1, a source S of 120 Volt/60 Hz voltage is connected with full-bridge rectifier FBR. Positive output terminal OTa of rectifier FBR is connected directly with a B+ bus; and negative output terminal OTb of rectifier FBR is connected directly with a B− bus.

Between the B+ bus and the B− bus is connected a series-combination of two capacitors C1 and C2, which two capacitors are connected together at a junction CJ.

Between the B+ bus and the B− bus is also connected a series-combination of two transistors Q1 and Q2.

The secondary winding CT1s of positive feedback current transformer CT1 is connected directly between the base and the emitter of transistor Q1; and the secondary winding CT2s of positive feedback current transformer CT2 is connected directly between the base and the emitter of transistor Q2.

The collector of transistor Q1 is connected directly with the B+ bus; the emitter of transistor Q2 is connected directly with the B− bus; and the emitter of transistor Q1 is connected directly with the collector of transistor Q2, thereby forming junction QJ.

The series-connected primary windings CT1p and CT2p are connected directly between junction QJ and a point X; while the primary winding Tp of transformer T is connected between point X and junction CJ.

Transformer T has a secondary winding Ts, which is connected directly with an incandescent lamp IL.

A resistor R1 is connected with its one terminal to the B+ bus and with its other terminal to point X. Another resistor R2 is connected between point X and one terminal of a variable resistor R3. The other terminal of R3 is connected to junction DJ, to which junction is also connected one of the terminals of a capacitor C3. The other terminal of C3 is connected to the B− bus.

A Diac D is connected between junction DJ and the base of transistor Q2.

A rectifier R is connected with its anode to junction DJ and with its cathode to junction QJ.

A control transistor CQ is connected with its collector to the junction JR between resistors R2 and R3, and with its emitter to the B− bus. A resistor R4 is connected between the control transistor's base and emitter; and a resistor R5 is connected between a control terminal CT1 and the base of the control transistor. Another control terminal CT2 is connected directly with the B− bus.

The overall inverter is identifed with the letter I.

Actual values and descriptions of the components used in the preferred arrangement in FIG. 1 are listed as follows.

Output of Source S:	120 Volt/60 Hz;
Full Bridge Rectifier FBR:	Four 1N4004's;
Capacitors C1 & C2:	0.47 μF/200 Volt;
Transistors Q1 & Q2:	Motorola MJE13002's;
Transistor CQ:	Motorola MXT3904;
Resistor R1:	33 kOhm/0.25 Watt;
Resistor R2:	100 kOhm/0.25 Watt;
Adjustable Resistor R3:	1.5 MegOhm Potentiometer;
Resistor R4:	22 kOhm/0.25 Watt;
Resistor R5:	47 kOhm/0.25 Watt;
Capacitor C3:	22 nF/50 Volt;
Rectifier R:	1N4004;
Diac D:	General Electric ST-2;
Transformers CT1 & CT2:	Wound on Ferroxcube Toroids 213T050 of 3E2A Ferrite Material with two turns of #27 wire for the primary windings and ten turns of #31 wire for the secondary windings;
Transformer T:	Wound on a Ferroxcube 2616 Pot Core of 3C8 Ferrite Material with 95 turns of #27 wire for the primary winding and 20 turns of five twisted strands of #27 wire for the secondary winding;
Incandescent Lamp IL:	12 Volt/25 Watt.

The frequency of inverter oscillation associated with the component values identified above is approximately 30 kHz.

In FIG. 2a, the waveform identified as Wa represents the voltage Vi present between the B− bus and the B+ bus as plotted against time t. The magnitude of voltage Vi at the time t1 when the inverter is triggered into oscillation is indicated as Vi1. The magnitude of voltage Vi at the time t2 the inverter drops out of oscillation is indicated as Vi2.

In FIG. 2b, the waveform identified as Wb represents the inverter output voltage Vo plotted against time t; which output voltage exists across the secondary winding Ts of transformer T in FIG. 1, and which is the voltage provided to incandescent lamp IL.

FIG. 3 illustrates one particular use of the controllable inverter power supply of FIG. 1. In particular, the circuit arrangement of FIG. 3 is identical with that of FIG. 1 except for having added an automatic feedback control arrangement by way of having placed a light sensitive resistor LSR, such as a selenium semiconductor means, in the proximity of lamp IL and such as to be exposed to part of the light emitted from IL. The light sensitive resistor LSR is connected between the positive terminal of a DC source DCS and control terminal CT1. The negative terminal of DCS is connected directly with control terminal CT2.

Description of Operation

The operation of the circuit arrangement of FIG. 1 is described as follows.

Source S represents an ordinary 120 Volt/60 Hz electric utility power line, the voltage from which is rectified in full-wave fashion by full-bridge rectifier means FBR. Thus, in the absence of filtering means, the voltage present across output terminals OTa and OTb is substantially as depicted in FIG. 2a; which voltage is applied directly to the inverter circuit I.

This inverter circuit, which consists of the two series-connected switching transistors Q1 and Q2 in combination with the two positive feedback transformers CT1 and CT2, represents a self-oscillating half-bridge inverter and operates in a manner that is analogous with circuits previously described in published literature, as for instance in U.S. Pat. No. 4,184,128 entitled High Efficiency Push-Pull Inverters.

Since the DC voltage-supply feeding the inverter has no filtering capacitors, it is necessary to provide within the inverter a low impedance return path for the inverter current. Such a low impedance return path is provided by way of the two series-connected capacitors C1 and C2. However, it is necessary that the capacitance values of these capacitors be kept small enough not to represent significant energy-storing capacity in comparison to the amount of energy being drawn by the inverter over a half-cycle of the power line voltage. In this case, with the power drawn being about 25 Watt (which is about 208 milli-Joule per half-cycle of the 60 Hz power line voltage) the energy stored by the two series-connected 0.47 uF capacitors is indeed small in comparison (being only 2.6 milli-Joule at 150 Volt).

In the inverter circuit of FIG. 1, the bases of the transistors are—in terms of DC—shorted to their emitters; which implies that the inverter can not start oscillating by itself. However, by providing but a single brief pulse to the base of transistor Q2, this transistor is caused to conduct momentarily; which momentary conduction puts this one transistor into an amplifying situation; which is enough to trigger the inverter into oscillation—provided, of course, that there is adequate voltage present between the B− bus and the B+ bus.

Once triggered into oscillation, the inverter will continue to oscillate until the voltage between the B− bus and the B+ bus falls to such a low level as to be inadequate for sustaining regenerative feedback. At this point, which is identified as Vi2 in FIG. 2*a*, oscillations cease.

Inverter triggering is accomplished by way of a Diac; which Diac itself is triggered by the voltage on capacitor C3.

The output of the half-bridge inverter circuit is a substantially squarewave 30 kHz AC voltage, which output is provided between point X and junction CJ, and across which output is connected the primary winding of transformer T. The peak-to-peak amplitude of this 30 kHz squarewave voltage is substantially equal to the magnitude of the DC voltage present between the B− bus and the B+ bus; and therefore, as the magnitude of this DC voltage varies, so does the amplitude of the 30 kHz squarewave output voltage.

The incandescent lamp IL is connected directly across the secondary winding Ts of transformer T; which means that the voltage presented to the incandescent lamp is directly proportional to the inverter circuit output voltage.

Being supplied with a pulsed DC voltage similar to that depicted in FIG. 2*a*, the inverter circuit—even if oscillating at some given moment—will cease oscillating when the DC supply voltage falls below a certain minimal level (Vi2 in FIG. 2*a*). Thus, if the inverter is triggered into oscillation at some time during each of the unidirectional sinusoidally-shaped voltage pulses constituting the DC supply voltage, it will cease to oscillate at or near the end of each of these pulses.

In other words, the inverter circuit of FIG. 1 behaves much like a Triac or a thyristor: it can be triggered ON, and will remain ON until the end of the power-cycle—that is, until current flowing to the load falls below a certain threshold level. And, just like a thyristor, it can be triggered at substantially any point within the power-cycle; which means that it can be phase-controlled in a manner analogous to that of a thyristor.

In yet other words, the RMS or average magnitude of the voltage provided to the incandescent lamp can be controlled over a wide range simply by controlling the timing of the inverter trigger point (t1 in FIG. 2).

Triggering of the inverter circuit is accomplished essentially the same way as is the triggering of a Triac, and phase control is accomplished in the same manner.

In FIG. 1, resistors R2 and R3 in combination constitute a resistance means through which capacitor C3 is charged. By adjusting the magnitude of the combined resistance, the time to charge capacitor C3 is similarly adjusted; which implies that the phase-point (i.e., t1 in FIG. 2*a*) at which the inverter is triggered into oscillation is correspondingly adjusted.

The purpose of rectifier R is that of making sure that capacitor C3 gets fully discharged after the inverter is triggered into oscillation; which implies that this capacitor will start each new power cycle in a fully discharged condition, thereby assuring time-consistent triggering.

The reason for having R2 as a resistor physically separate from R3 is that of preventing the voltage at point X from being applied directly to capacitor C3, which could provide for a situation of actually preventing triggering from taking place.

The purpose of resistor R1, the resistance value of which is quite small in comparison with that of R2 and R3 combined, is that of making sure that there is enough voltage at junction CJ (relative to the B− bus) to permit the inverter circuit to be triggered into oscillation.

The function of control transistor CQ is that of providing for an electrically actuatable means by which the triggering of Diac D can be controlled. When there is no control voltage provided between control terminals CT1 and CT2, transistor CQ is non-conducting, and the trigger circuit (which consists of resistors R2 and R3, capacitor C3 and Diac D) will operate as if CQ is non-present. However, as an increasing positive voltage is provided to control terminal CT1, CQ will eventually start to conduct and thereby to shunt charging current away from capacitor C3. The more positive current that is provided into the base of CQ, the more charging current is shunted away from C3. Eventually, with a relatively high positive voltage provided at control terminal CT1, CQ gets so much base current that its shunting effect entirely prevents C3 to charge to a voltage high enough to provide triggering pulses.

Thus, by providing a unidirectional control voltage between control terminals CT1 and CT2—with the positive terminal of the control voltage being connected with CT1—electrically actuatable inverter trigger control results; which implies that the 30 kHz inverter output voltage can be electrically switched ON and/or OFF, as well as continuously controlled in terms of magnitude.

The arrangement of FIG. 3 demonstrates one way in which the control capability of the circuit of FIG. 1 can be put to use. The light output of lamp IL affects inverter triggering in such a way that increased light output will cause reduction in the RMS magnitude of the 30 kHz voltage output; which implies that—since light output is proportional to the RMS magnitude of the lamp voltage—the RMS magnitude of the lamp voltage will tend to remain constant even if the RMS magnitude of the power line voltage might change.

Another application in which the power supply of FIG. 1 can advantageously be used is as an electrically controllable source of power for the magnetron in a microwave oven—i.e., where the load would be a magnetron and not an incandescent lamp. In such an application, it would be desirable to have an electronic programming means be able to control the amount of power supplied to the microwave magnetron; which, of course, can be readily accomplished by way of having this programming means provide appropriate control voltages to control terminals CT1 and CT2.

Otherwise, the following comments are offered.

(a) The concept of feeding an inverter with a pulsed DC voltage and to have its oscillations phase controlled (in relationship to the phasing of the DC pulses) is not limited to be used with a half-bridge inverter circuit. Most any type of self-oscillating inverter circuit may be used, the chief criterion being that the inverter circuit must be of such a nature as to have to be triggered into oscillation.

(b) To achieve a reasonably wide range of control of RMS output voltage, it is important that the inverter be capable of sustained self-oscillation even at relatively low levels of DC supply voltage. In the circuit of FIG. 1, stable inverter self-oscillation is sustained down to a DC supply voltage of about 20 Volt; below which voltage oscillations abruptly cease.

It is believed that the present invention and its several attendant advantages and features will be understood from the preceeding description. However, without departing from the spirit of the invention, changes may be made in its form and in the construction and interrelationships of its component parts, the form herein presented merely representing the preferred embodiment.

I claim:

1. An arrangement comprising:

a power line providing a power line voltage at a pair of power line terminals;

an incandescent lamp having a pair of lamp terminals; and

means connected in circuit between the power line terminals and the lamp terminals; the means being functional to provide a lamp voltage to the lamp terminals; the lamp voltage consisting of periodic bursts of high frequency voltage; the fundamental frequency of the high frequency voltage being substantially higher than that of the power line voltage; the periodic bursts of high frequency voltage being separated with intervals of zero voltage; each interval of zero voltage having a duration substantially longer than that of a complete cycle of the high frequency voltage.

2. The arrangement of claim 1 wherein: (i) the power line voltage has cycles; and (ii) the bursts of high frequency voltage occur in synchrony with the cycles of the power line voltage.

3. The arrangement of claim 1 wherein: (i) each periodic burst of the high frequency voltage has a period; and (ii) the peak-to-peak magnitude of the high frequency voltage is caused to vary by a substantial degree during this period.

4. The arrangement of claim 1 wherein, during each periodic burst, the peak-to-peak magnitude of the high frequency voltage is proportional to the instantaneous absolute magnitude of the power line voltage.

5. The arrangement of claim 1 wherein, during each periodic burst, the instantaneous absolute magnitude of the high frequency voltage is proportional to that of the power line voltage.

6. The arrangement of claim 1 wherein said means includes means for controlling the duration of each interval of zero voltage.

7. The arrangement of claim 1 wherein: (i) the power line voltage has a fundamental frequency on the order of 60 Hz; and (ii) the high frequency voltage has a fundamental frequency on the order of 30 kHz.

8. A combination comprising:

a power line providing a power line voltage at a pair of power line terminals; the power line voltage having a first fundamental frequency;

an incandescent lamp having a pair of lamp terminals; and

frequency-converting voltage conditioning means connected in circuit between the power line terminals and the lamp terminals; the frequency-converting voltage conditioning means being functional to provide a lamp voltage to the lamp terminals; the lamp voltage consisting of periodic bursts of high frequency voltage; the periodic bursts occurring at a rate equal to twice the first fundamental frequency; the high frequency voltage having a second fundamental frequency; the second fundamental frequency being substantially higher than the first fundamental frequency; the periodic bursts of high frequency voltage being separated with intervals of zero magnitude voltage; each interval of zero magnitude voltage having a duration substantially longer than that of a complete cycle of the high frequency voltage.

9. The combination of claim 8 wherein said frequency-converting voltage conditioning means includes adjustment means operative to permit adjustment of said duration, thereby to permit adjustment of the RMS magnitude of the lamp voltage.

10. The combination of claim 8 wherein the frequency-converting voltage conditioning means includes transformer means operative to provide galvanic isolation between the lamp terminals and the power line terminals, thereby to prevent any substantial amount of current from flowing between the power line terminals and the lamp terminals by way of the frequency-converting voltage conditioning means.

11. A combination comprising:

a source providing 60 Hz voltage at a pair of power line terminals;

an incandescent lamp having lamp terminals; and

means connected between the power line terminals and the lamp terminals; the means providing periodic bursts of 30 kHz voltage to the lamp terminals; the bursts of 30 kHz voltage being separated with intervals of zero magnitude voltage; each interval of zero magnitude voltage having a duration longer than that of a complete cycle of the 30 kHz voltage; the intervals of zero magnitude voltage occurring at a rate of 120 Hz.

12. The combination of claim 11 wherein, during each burst, the peak magnitude of the 30 kHz voltage varies substantially in proportion to the instantaneous absolute magnitude of the 60 Hz voltage.

13. The combination of claim 11 wherein said means includes a feature whereby said duration may be adjusted.

14. The combination of claim 11 wherein said means includes:

rectifier means connected with the power line terminals and operative to provide a DC voltage at a set of DC terminals; the DC voltage having an instantaneous absolute magnitude that is, at least during a part of each cycle of the 60 Hz voltage, substantially equal to the instantaneous absolute magnitude of the 60 Hz voltage;

inverter means connected with the DC terminals and operative, at least during a part of each cycle of the 60 Hz voltage, to provide a substantially squarewave voltage at a pair of inverter terminals; the instantaneous absolute magnitude of the square-wave voltage being, at least during a part of each cycle of the 60 Hz voltage, substantially proportional to the instantaneous absolute magnitude of the 60 Hz voltage; and

transformer means connected between the inverter terminals and the lamp terminals; thereby to provide to the lamp terminals a substantially square-wave voltage having, at least during a part of each cycle of the 60 Hz voltage, an instantaneous absolute magnitude that is proportional to the instantaneous absolute magnitude of the 60 Hz voltage.

15. The combination of claim **11** wherein, during each burst, the absolute instantaneous magnitude of the voltage provided to the lamp terminals equals a substantially constant fraction of the instantaneous absolute magnitude of the 60 Hz voltage.

16. The combination of claim **11** wherein, during each burst, the RMS magnitude of the voltage provided to the lamp terminals equals a substantially constant fraction of the instantaneous absolute magnitude of the 60 Hz voltage; the RMS magnitude being computed over the duration of a complete half-cycle of the 30 kHz voltage.

* * * * *

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US005083255A

United States Patent [19]

Nilssen

[11] **Patent Number: 5,083,255**

[45] **Date of Patent: * Jan. 21, 1992**

[54] **INVERTER WITH ELECTRICALLY CONTROLLABLE OUTPUT**

[76] Inventor: **Ole K. Nilssen**, Caesar Dr., Rte. 5, Barrington, Ill. 60010

[*] Notice: The portion of the term of this patent subsequent to Mar. 19, 2002 has been disclaimed.

[21] Appl. No.: **548,197**

[22] Filed: **Jul. 5, 1990**

Related U.S. Application Data

[63] Continuation of Ser. No. 667,691, Nov. 2, 1984, abandoned, which is a continuation-in-part of Ser. No. 487,817, Apr. 22, 1983, Pat. No. 4,506,318.

[51] **Int. Cl.⁵** **H02M 7/44**

[52] **U.S. Cl.** **363/132; 363/98**

[58] **Field of Search** 323/242, 325, 326; 363/17, 18, 19, 22, 23, 34, 37, 38, 39, 98, 131, 132, 157, 159, 163, 164, 165

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Primary Examiner—R. Skudy
Assistant Examiner—Judson H. Jones

[57] **ABSTRACT**

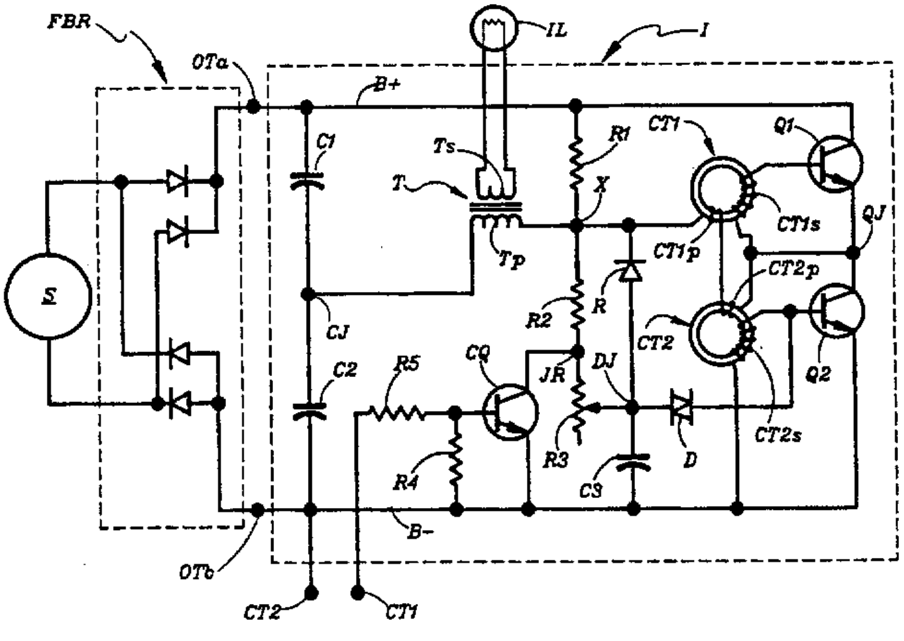
An inverter is powered by the pulsed DC voltage obtained by unfiltered full-wave rectification of the 60 Hz voltage from a regular electric utility power line. As long as the magnitude of the DC supply voltage is higher than a certain threshold level, the inverter can be triggered into 30 kHz self-sustaining oscillation. However, this oscillation stops as soon as the magnitude of the DC supply voltage falls below this certain threshold level. Thereafter, the inverter will not restart its oscillation, regardless of the magnitude of the DC supply voltage, except if provided with another trigger signal.

Thus, the inverter can be made to operate in fashion analogous to that of a thyristor: Once triggered, the inverter will provide a 30 kHz output of magnitude substantially proportional to that of its DC supply voltage;' but as soon as the magnitude of its DC supply voltage decreases below a certain threshold level, as indeed occurs once every half-cycle of the 60 Hz voltage, it will cease to provide an output.

To provide a substantially continuous output of 30 kHz voltage, the inverter has to be triggered each half-cycle of the 60 Hz voltage, the trigger phasing being determinative of the RMS magnitude of the output voltage. If continuous triggering is not provided, no 30 kHz output voltage results.

Means are provided by which the triggering and its phasing are controlled electrically, thereby providing for an inverter with electrically controllable output voltage.

14 Claims, 2 Drawing Sheets



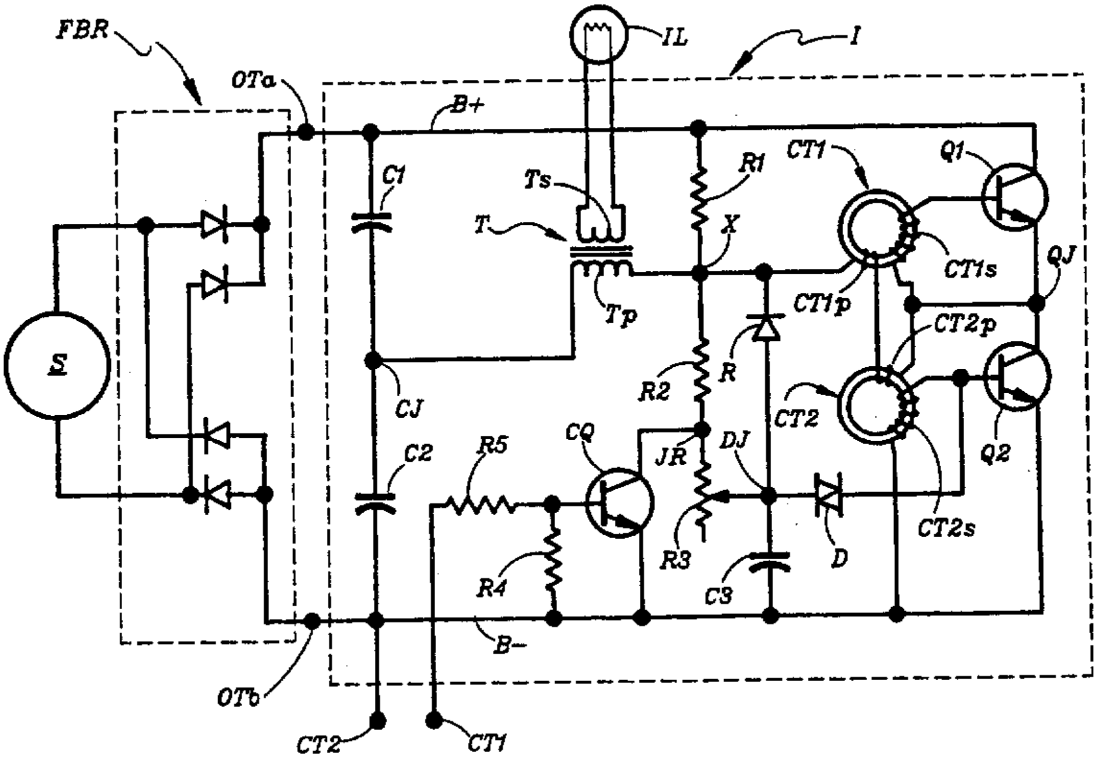


Fig. 1

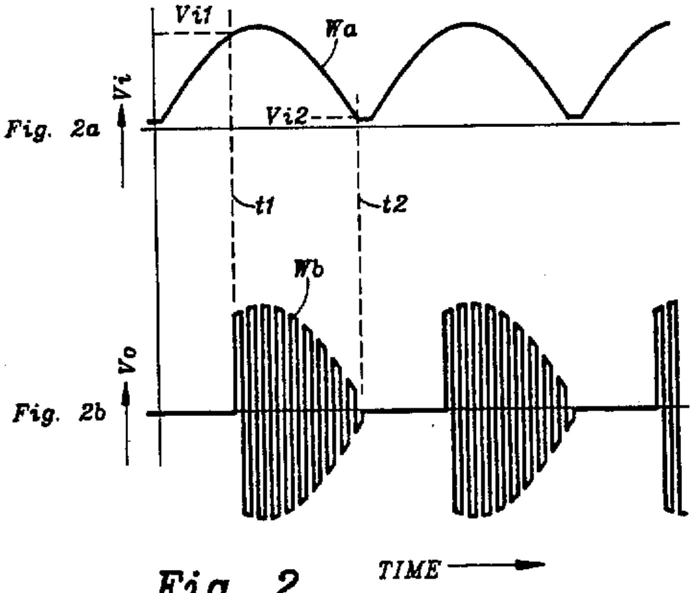


Fig. 2a

Fig. 2b

Fig. 2

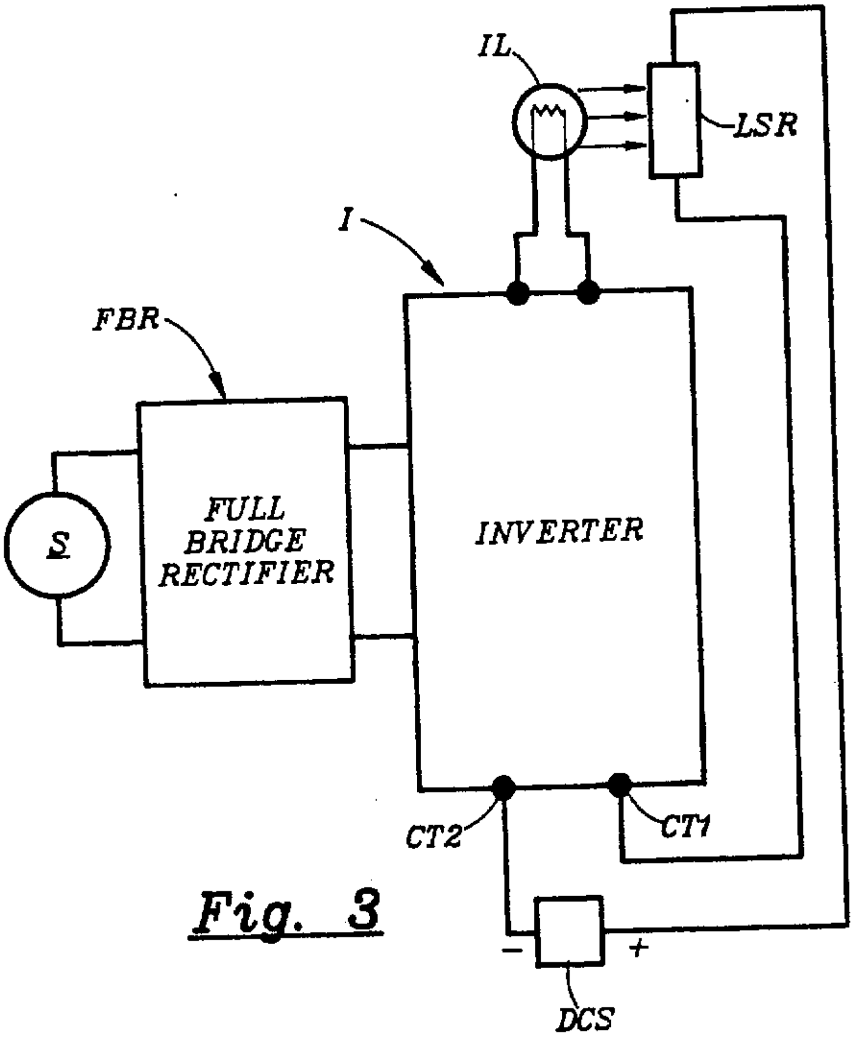


Fig. 3

INVERTER WITH ELECTRICALLY CONTROLLABLE OUTPUT

BACKGROUND OF THE INVENTION

Continuation-in-Part

This application is a continuation of Ser. No. 06/667,691 filed on Nov. 2, 1984, now abandoned which is a continuation-in-part of application Ser. No. 06/487,817 filed on Apr. 22, 1983.

FIELD OF INVENTION

The present invention relates to power-line-operated inverter-type power supplies with means for electrically controlling the inverter output voltage.

DESCRIPTION OF PRIOR ART

Power-line-operated inverter-type power supplies are presently being used in a variety of applications. For instance, such power supplies are frequently being used for powering low-voltage incandescent lamps.

When using such inverter-type power supplies in connection with powering various loads, such as low-voltage incandescent lamps or microwave magnetrons, it is sometimes desirable to be able by way of electrically actuatable means to control the inverter output voltage, thereby providing for control of the power provided to the load. However, to provide cost-effectively for electrically actuatable means to effect control of the output of inverters is not as simple as it might initially appear.

Of course, to achieve such control, one might use an electrically actuatable variable-ratio transformer (Variac) between the power line and the input of the power supply. However, the cost and complexities associated with such an approach would be unacceptably high in most applications.

Or, one might consider the use of a Triac-type voltage control means mounted between the power line and the power supply. However, Triac-type voltage control means simply do not function properly with the kind of input characteristics normally associated with power-line-operated inverter-type power supplies.

Then, there is the possibility of using an inverter-type power supply with a special input circuit that would permit the use of a Triac-type control means; which input circuit would then have to make the inverter power-input-characteristics appear substantially like a resistive load. Even so, however, there is the cost and the electrical inefficiency of the Triac-type control to consider.

The present invention represents yet another solution; which other solution is novel, less costly and electrically more efficient than that of using a Triac-type control means between the power line and the inverter input.

SUMMARY OF THE INVENTION

Objects of Invention

An object of the present invention is that of providing a power-line-operated inverter-type power supply having electrically actuatable means to permit output voltage control.

This as well as other objects, features and advantages of the present invention will become apparent from the following description and claims.

BRIEF DESCRIPTION

In its preferred embodiment, subject invention is a power supply adapted to be powered from the regular 60 Hz power line voltage and to provide an output of relatively high-frequency (30 kHz) substantially square-wave voltage. This output voltage is provided by an inverter that is powered by way of the pulsed DC voltage derived from unfiltered full-wave rectification of the 60 Hz power line voltage. Thus, the high-frequency inverter output voltage is pulse-amplitude-modulated at a 120 Hz rate—in correspondence with the pulse-amplitude-modulations of the pulsed DC supply voltage.

The inverter is of a type that has to be triggered into oscillation. However, once triggered, it will continue to oscillate, but only for as long as the instantaneous magnitude its pulsed DC supply voltage exceeds a certain threshold level.

Since the pulsed DC supply voltage falls to zero magnitude between each pulse, the inverter stops oscillating between each pulse. Thus, as long as output voltage is desired, the inverter has to be re-triggered after each pulse of the DC supply voltage.

Inverter triggering is accomplished by a Diac in combination with an RC integrating circuit; which means that—upon each application of a pulse of DC supply voltage—the inverter is triggered into oscillation only after the DC supply voltage has been present for some period of time; the length of this period being determined by the nature of the RC integrating circuit—much in the same way as phase-control is accomplished in an ordinary Triac-type incandescent lamp dimmer.

Connected with the RC integrating circuit is a control transistor, the effective impedance of which can be varied over a wide range by way of an electrical control voltage. With this control voltage having a relatively low magnitude, the inverter is triggered into oscillation quite early in the period of each pulse of the DC supply voltage; whereas, with this control voltage having a relatively large magnitude, no inverter triggering takes place at all.

For in-between magnitudes of the control voltage, inverter triggering takes place at substantially corresponding in-between delays relative to the onset of each DC pulse; which means that the net effective RMS magnitude of the output voltage can be adjusted by adjusting the magnitude of the control voltage.

Thus, by providing a control voltage to a pair of control terminals, the magnitude of the inverter output voltage can be adjusted over a wide range: from a maximum and all the way down to zero output—with a response time equal to half a cycle of the 60 Hz power line voltage.

By sensing the average or RMS magnitude of the inverter output voltage and by providing a control voltage to the control transistor that is effectively proportional to that average or RMS magnitude, output magnitude control can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates the preferred embodiment of the invention, showing an inverter-type power supply adapted to power a low-voltage incandescent lamp.

FIG. 2*a* illustrates the waveform of the DC supply voltage used for powering the inverter; and FIG. 2*b* illustrates the waveform of the inverter's squarewave output voltage.

FIG. 3 illustrates the circuit of FIG. 1 arranged with feedback means operative to automatically control the RMS magnitude of the inverter output voltage.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Description of the Drawings

In FIG. 1, a source S of 120 Volt/60 Hz voltage is connected with full-bridge rectifier FBR. Positive output terminal OTa of rectifier FBR is connected directly with a B+ bus; and negative output terminal OTb of rectifier FBR is connected directly with a B− bus.

Between the B+ bus and the B− bus is connected a series-combination of two capacitors C1 and C2, which two capacitors are connected together at a junction CJ.

Between the B+ bus and the B− bus is also connected a series-combination of two transistors Q1 and Q2.

The secondary winding CT1s of positive feedback current transformer CT1 is connected directly between the base and the emitter of transistor Q1; and the secondary winding CT2s of positive feedback current transformer CT2 is connected directly between the base and the emitter of transistor Q2.

The collector of transistor Q1 is connected directly with the B+ bus; the emitter of transistor Q2 is connected directly with the B− bus; and the emitter of transistor Q1 is connected directly with the collector of transistor Q2, thereby forming junction QJ.

The series-connected primary windings CT1p and CT2p are connected directly between junction QJ and a point X; while the primary winding Tp of transformer T is connected between point X and junction CJ.

Transformer T has a secondary winding Ts, which is connected directly with an incandescent lamp IL.

A resistor R1 is connected with its one terminal to the B+ bus and with its other terminal to point X. Another resistor R2 is connected between point X and one terminal of a variable resistor R3. The other terminal of R3 is connected to junction DJ, to which junction is also connected one of the terminals of a capacitor C3. The other terminal of C3 is connected to the B− bus.

A Diac D is connected between junction DJ and the base of transistor Q2.

A rectifier R is connected with its anode to junction DJ and with its cathode to junction QX.

A control transistor CQ is connected with its collector to the junction JR between resistors R2 and R3, and with its emitter to the B− bus. A resistor R4 is connected between the control transistor's base and emitter; and a resistor R5 is connected between a control terminal CT1 and the base of the control transistor. Another control terminal CT2 is connected directly with the B− bus.

The overall inverter is identifed with the letter I.

Actual values and descriptions of the components used in the preferred arrangement in FIG. 1 are listed as follows.

Output of Source S:	120 Volt/60 Hz;
Full Bridge Rectifier FBR:	Four 1N4004's;
Capacitors C1 & C2:	0.47 uF/200 Volt;
Transistors Q1 & Q2:	Motorola MJE13002's;
Transistor CQ:	Motorola MXT3904;
Resistor R1:	33k Ohm/0.25 Watt;
Resistor R2:	100k Ohm/0.25 Watt;
Adjustable Resistor R3:	1.5 MegOhm Potentiometer;
Resistor R4:	22k Ohm/0.25 Watt;
Resistor R5:	47k Ohm/0.25 Watt;
Capacitor C3:	22 nF/50 Volt;
Rectifier R:	1N4004;
Diac D:	General Electric ST-2;
Transformers CT1 & CT2:	Wound on Ferroxcube Toroids 213T050 of 3E2A Ferrite Material with two turns of #27 wire for the primary windings and ten turns of #31 wire for the secondary windings;
Transformer T:	Wound on a Ferroxcube 2616 Pot Core of 3C8 Ferrite Material with 95 turns of #27 wire for the primary winding and 20 turns of five twisted strands of #27 wire for the secondary winding;
Incandescent Lamp IL:	12 Volt/25 Watt.

The frequency of inverter oscillation associated with the component values identified above is approximately 30 kHz.

In FIG. 2*a*, the waveform identified as Wa represents the voltage Vi present between the B− bus and the B+ bus as plotted against time t. The magnitude of voltage Vi at the time t1 when the inverter is triggered into oscillation is indicated as Vi1. The magnitude of voltage Vi at the time t2 the inverter drops out of oscillation is indicated as Vi2.

In FIG. 2*b*, the waveform identified as Wb represents the inverter output voltage Vo plotted against time t; which output voltage exists across the secondary winding Ts of transformer T in FIG. 1, and which is the voltage provided to incandescent lamp IL.

FIG. 3 illustrates one particular use of the controllable inverter power supply of FIG. 1. In particular, the circuit arrangement of FIG. 3 is identical with that of FIG. 1 except for having added an automatic feedback control arrangement by way of having placed a light sensitive resistor LSR, such as a selenium semiconductor means, in the proximity of lamp IL and such as to be exposed to part of the light emitted from IL. The light sensitive resistor LSR is connected between the positive terminal of a DC source DCS and control terminal CT1. The negative terminal of DCS is connected directly with control terminal CT2.

DESCRIPTION OF OPERATION

The operation of the circuit arrangement of FIG. 1 is described as follows.

Source S represents an ordinary 120 Volt/60 Hz electric utility power line, the voltage from which is rectified in full-wave fashion by full-bridge rectifier means FBR. Thus, in the absence of filtering means, the voltage present across output terminals OTa and OTb is substantially as depicted in FIG. 2*a*; which voltage is applied directly to the inverter circuit I.

This inverter circuit, which consists of the two series-connected switching transistors Q1 and Q2 in combination with the two positive feedback transformers CT1 and CT2, represents a self-oscillating half-bridge inverter and operates in a manner that is analogous with circuits previously described published literature, as for instance in U.S. Pat. No. 4,184,128 entitled High Efficiency Push-Pull Inverters.

Since the DC voltage-supply feeding the inverter has no filtering capacitors, it is necessary to provide within the inverter a low impedance return path for the inverter current. Such a low impedance return path is provided by way of the two series-connected capacitors C1 and C2. However, it is necessary that the capacitance values of these capacitors be kept small enough not to represent significant energy-storing capacity in comparison to the amount of energy being drawn by the inverter over a half-cycle of the power line voltage. In this case, with the power drawn being about 25 Watt (which is about 208 milliJoule per half-cycle of the 60 Hz power line voltage) the energy stored by the two series-connected 0.47 uF capacitors is indeed small in comparison (being only 2.6 milli-Joule at 150 Volt).

In the inverter circuit of FIG. 1, the bases of the transistors are—in terms of DC—shorted to their emitters; which implies that the inverter can not start oscillating by itself. However, by providing but a single brief pulse to the base of transistor Q2, this transistor is caused to conduct momentarily; which momentary conduction puts this one transistor into an amplifying situation; which is enough to trigger the inverter into oscillation—provided, of course, that there is adequate voltage present between the B− bus and the B+ bus.

Once triggered into oscillation, the inverter will continue to oscillate until the voltage between the B− bus and the B+ bus falls to such a low level as to be inadequate for sustaining regenerative feedback. At this point, which is identified as Vi2 in FIG. 2*a*, oscillations cease.

Inverter triggering is accomplished by way of a Diac; which Diac itself is triggered by the voltage on capacitor C3.

The output of the half-bridge inverter circuit is a substantially squarewave 30 kHz AC voltage, which output is provided between point X and junction CJ, and across which output is connected the primary winding of transformer T. The peak-to-peak amplitude of this 30 kHz squarewave voltage is substantially equal to the magnitude of the DC voltage present between the B− bus and the B+ bus; and therefore, as the magnitude of this DC voltage varies, so does the amplitude of the 30 kHz squarewave output voltage.

The incandescent lamp IL is connected directly across the secondary winding Ts of transformer T; which means that the voltage presented to the incandescent lamp is directly proportional to the inverter circuit output voltage.

Being supplied with a pulsed DC voltage similar to that depicted in FIG. 2*a*, the inverter circuit—even if oscillating at some given moment—will cease oscillating when the DC supply voltage falls below a certain minimal level (Vi2 in FIG. 2*a*). Thus, if the inverter is triggered into oscillation at some time during each of the unidirectional sinusoidally-shaped voltage pulses constituting the DC supply voltage, it will cease to oscillate at or near the end of each of these pulses.

In other words, the inverter circuit of FIG. 1 behaves much like a Triac or a thyristor: it can be triggered ON, and will remain ON until the end of the power-cycle—that is, until current flowing to the load falls below a certain threshold level. And, just like a thyristor, it can be triggered at substantially any point within the power-cycle; which means that it can be phase-controlled in a manner analogous to that of a thyristor.

In yet other words, the RMS or average magnitude of the voltage provided to the incandescent lamp can be controlled over a wide range simply by controlling the timing of the inverter trigger point (t1 in FIG. 2).

Triggering of the inverter circuit is accomplished essentially the same way as is the triggering of a Triac, and phase control is accomplished in the same manner.

In FIG. 1, resistors R2 and R3 in combination constitute a resistance means through which capacitor C3 is charged. By adjusting the magnitude of the combined resistance, the time to charge capacitor C3 is similarly adjusted; which implies that the phase-point (i.e., t1 in FIG. 2*a*) at which the inverter is triggered into oscillation is correspondingly adjusted.

The purpose of rectifier R is that of making sure that capacitor C3 gets fully discharged after the inverter is triggered into oscillation; which implies that this capacitor will start each new power cycle in a fully discharged condition, thereby assuring time-consistent triggering.

The reason for having R2 as a resistor physically separate from R3 is that of preventing the voltage at point X from being applied directly to capacitor C3, which could provide for a situation of actually preventing triggering from taking place.

The purpose of resistor R1, the resistance value of which is quite small in comparison with that of R2 and R3 combined, is that of making sure that there is enough voltage at junction CJ (relative to the B− bus) to permit the inverter circuit to be triggered into oscillation.

The function of control transistor CQ is that of providing for an electrically actuatable means by which the triggering of Diac D can be controlled. When there is no control voltage provided between control terminals CT1 and CT2, transistor CQ is non-conducting, and the trigger circuit (which consists of resistors R2 and R3, capacitor C3 and Diac D) will operate as if CQ is non-present. However, as an increasing positive voltage is provided to control terminal CT1, CQ will eventually start to conduct and thereby to shunt charging current away from capacitor C3. The more positive current that is provided into the base of CQ, the more charging current is shunted away from C3. Eventually, with a relatively high positive voltage provided at control terminal CT1, CQ gets so much base current that its shunting effect entirely prevents C3 to charge to a voltage high enough to provide triggering pulses.

Thus, by providing a unidirectional control voltage between control terminals CT1 and CT2—with the positive terminal of the control voltage being connected with CT1—electrically actuatable inverter trigger control results; which implies that the 30 kHz inverter output voltage can be electrically switched ON and/or OFF, as well as continuously controlled in terms of magnitude.

The arrangement of FIG. 3 demonstrates one way in which the control capability of the circuit of FIG. 1 can be put to use. The light output of lamp IL affects inverter triggering in such a way that increased light output will cause reduction in the RMS magnitude of the 30 kHz voltage output; which implies that—since light output is proportional to the RMS magnitude of the lamp voltage—the RMS magnitude of the lamp voltage will tend to remain constant even if the RMS magnitude of the power line voltage might change.

Another application in which the power supply of FIG. 1 can advantageously be used is as an electrically controllable source of power for the magnetron in a microwave oven—i.e., where the load would be a magnetron and not an incandescent lamp. In such an application, it would be desirable to have an electronic programming means be able to control the amount of power supplied to the microwave magnetron; which, of course, can be readily accomplished by way of having this programming means provide appropriate control voltages to control terminals CT1 and CT2.

Otherwise, the following comments are offered.

a) The concept of feeding an inverter with a pulsed DC voltage and to have its oscillations phase controlled (in relationship to the phasing of the DC pulses) is not limited to be used with a half-bridge inverter circuit. Most any type of self-oscillating inverter circuit may be used, the chief criterion being that the inverter circuit must be of such a nature as to have to be triggered into oscillation.

b) To achieve a reasonably wide range of control of RMS output voltage, it is important that the inverter be capable of sustained self-oscillation even at relatively low levels of DC supply voltage. In the circuit of FIG. 1, stable inverter self-oscillation is sustained down to a DC supply voltage of about 20 Volt; below which voltage oscillations abruptly cease.

It is believed that the present invention and its several attendant advantages and features will be understood from the preceeding description. However, without departing from the spirit of the invention, changes may be made in its form and in the construction and interrelationships of its component parts, the form herein presented merely representing the preferred embodiment.

I claim:

1. A power supply adapted to be powered from the relatively low frequency voltage on a regular electric power line and to provide a relatively high frequency output voltage, comprising:

rectifier means connected with said power line and operative to provide a DC supply voltage, said DC supply voltage being characterized by having an instantaneous unidirectional magnitude that is substantially equal to the instantaneous absolute magnitude of said low frequency voltage, whereby said instantaneous unidirectional magnitude increases above a certain threshold level once for each half-cycle of said relatively low frequency voltage and decreases below said certain threshold level once for each of said half-cycles;

inverter connected with said DC supply voltage and operative to provide said relatively high frequency output voltage, said inverter characterized by: i) ceasing operation each time the instantaneous magnitude of said DC supply voltage decreases below said certain threshold level, ii) resuming operation each time after the magnitude of said DC supply voltage has increased above said certain threshold level, but only if provided with a trigger signal; and

electrically controllable trigger means operable to provide said trigger signal to said inverter some pre-selected time-period after each time the magnitude of said DC supply voltage has increased above said certain threshold level, the duration of said pre-selected time-period being less than that of said half-period;

whereby, as long as said trigger signals are being provided, said inverter starts and stops operation once during each of said half-cycles, thereby providing said high frequency output voltage for a pre-selected fraction of the duration of each of said half-cycles.

2. The power supply of claim 1 wherein said trigger means is operative by way of providing an adjustable voltage level to permit adjustment of the duration of said pre-selected time-period, resulting in a corresponding adjustment of said pre-selected fraction, thereby providing for electrically actuatable adjustment of the RMS magnitude of said output voltage, the RMS magnitude being referenced to the duration of said half-cycle.

3. The power supply of claim 1 wherein said trigger means is controllably operable to prevent said trigger signals from being provided during periods longer than the duration of said half cycle.

4. A power supply adapted to be powered from the relatively low frequency voltage on a regular electric power line and operative conditionally to provide a relatively high frequency output voltage, comprising:

rectifier means connected with said power line and operative to provide a non-filtered DC supply voltage;

conditionally oscillating inverter connected with said DC supply voltage and operative, when oscillating, to provide said output voltage, said inverter characterized by: i) ceasing oscillation whenever the magnitude of said DC supply voltage decreases below a certain minimum level, and ii) resuming oscillation after the magnitude of said DC supply voltage has increased above said certain minimum level, but then only after having received a trigger pulse; and

trigger means conditionally operative to provide said trigger pulse a pre-selected brief time-period each time after the magnitude of said DC supply voltage has increased above said certain minimum level, said time-period being shorter than the period of said low frequency voltage;

whereby, as long as said trigger pulse is provided each time after the magnitude of said DC supply voltage has increased above said certain minimum level, said relatively high frequency output voltage is provided intermittently and periodically, with a periodicity not higher than that of said line voltage.

5. The power supply of claim 4 wherein said trigger means is operable selectively to provide or withhold said trigger pulses, thereby providing for electrically actuatable means for controlling the presence and/or non-presence of said high frequency output voltage.

6. An arrangement comprising:

connect means; and

frequency-converting power control means operative by way of the connect means to be connected with a relatively low frequency AC voltage having a period and operative during a fraction of said period to provide a relatively high frequency AC voltage to a load, the instantaneous absolute magnitude of this high frequency voltage, when provided, being substantially independent of the nature of the load and substantially proportional to the instantaneous absolute magnitude of the low frequency voltage,

the frequency-converting power control means comprising electrically actuatable control means operable to control the magnitude of said fraction, thereby to control the RMS magnitude of said high frequency voltage, said RMS magnitude being computed over at least a half-cycle of said low frequency voltage.

7. The power control means of claim 6 additionally comprising feedback means operative to maintain relatively constant the RMS magnitude of the high frequency voltage provided to the load even though the magnitude of the low frequency voltage may change.

8. A combination comprising:

a source providing an AC voltage at a pair of AC terminals; the AC voltage having a period; and

frequency-converting power supply means connected with the AC terminals and operative to provide a high frequency voltage at an output; the high frequency voltage having: (i) a fundamental frequency that is substantially higher than that of the AC voltage; (ii) during a first part the period, an RMS magnitude that varies in proportion to the absolute instantaneous magnitude of the AC voltage; and (iii) during a second part of the period, an RMS magnitude that is substantially zero, and not propositional to the absolute magnitude of the power line voltage.

9. The combination of claim **8** wherein the frequency-converting power supply means includes control means operative to control the ratio between the first part and the second part.

10. A arrangement comprising:

a source operative to provide a power line voltage at a pair of power line terminals; the power line voltage being of a relatively low frequency and having a basic cycle period; the basic cycle period consisting of two half-cycle periods; and

conditioner means connected with the power line terminals and operative to provide a high-frequency output voltage at a pair of output terminals; the frequency of the high-frequency output voltage being substantially higher than that of the power line voltage; the magnitude of the high-frequency output voltage varying during each half-cycle period, being: (i) substantially proportional to the absolute magnitude of the power line voltage during a first part of each half-cycle period; and (ii) substantially zero, and not proportional to the absolute magnitude of the power line voltage, during a second part of each half-cycle period.

11. The power supply means of claim **10** including control means operative to permit control of the duration of said second part.

12. The power supply means of claim **10** wherein the sum of the duration of the first part and the duration of the second part equals the duration of the half-cycle period.

13. The power supply means of claim **10** combined with an incandescent lamp means connected with the output terminals.

14. A arrangement comprising:

a source operative to provide a power line voltage at a pair of power line terminals; the power line voltage being of a relatively low frequency and having a fundamental period; the fundamental period consisting of two half-cycles;

voltage conditioner means connected with the power line terminals and operative to provide a high-frequency output voltage at a pair of output terminals; the frequency of the high-frequency output voltage being substantially higher than that of the power line voltage; the peak-to-peak magnitude of the high-frequency output voltage varying during each half-cycle, being: (i) substantially proportional to the absolute magnitude of the power line voltage during a first part of each half-cycle period; and (ii) substantially zero during a second part of each half-cycle period; and

incandescent lamp means connected with the output terminals.

* * * * *

4

US005144202A

United States Patent [19]

Nilssen

[11] **Patent Number: 5,144,202**

[45] **Date of Patent: * Sep. 1, 1992**

[54] **HIGH-FREQUENCY POWER SUPPLY FOR INCANDESCENT LAMP**

[76] Inventor: **Ole K. Nilssen**, Caesar Dr., Barrington, Ill. 60010

[*] Notice: The portion of the term of this patent subsequent to Jul. 30, 2008 has been disclaimed.

[21] Appl. No.: **741,575**

[22] Filed: **Aug. 7, 1991**

Related U.S. Application Data

[63] Continuation of Ser. No. 548,197, Jul. 5, 1990, Pat. No. 5,083,255, which is a continuation of Ser. No. 667,691, Nov. 2, 1984, abandoned, which is a continuation-in-part of Ser. No. 487,817, Apr. 22, 1983, Pat. No. 4,506,318.

[51] **Int. Cl.**^{5} **H05B 41/00**

[52] **U.S. Cl.** **315/151**; 315/194; 315/224; 315/225; 315/362

[58] **Field of Search** .... 315/151, 194, 224, 225, 315/291, 311, 362, DIG. 4

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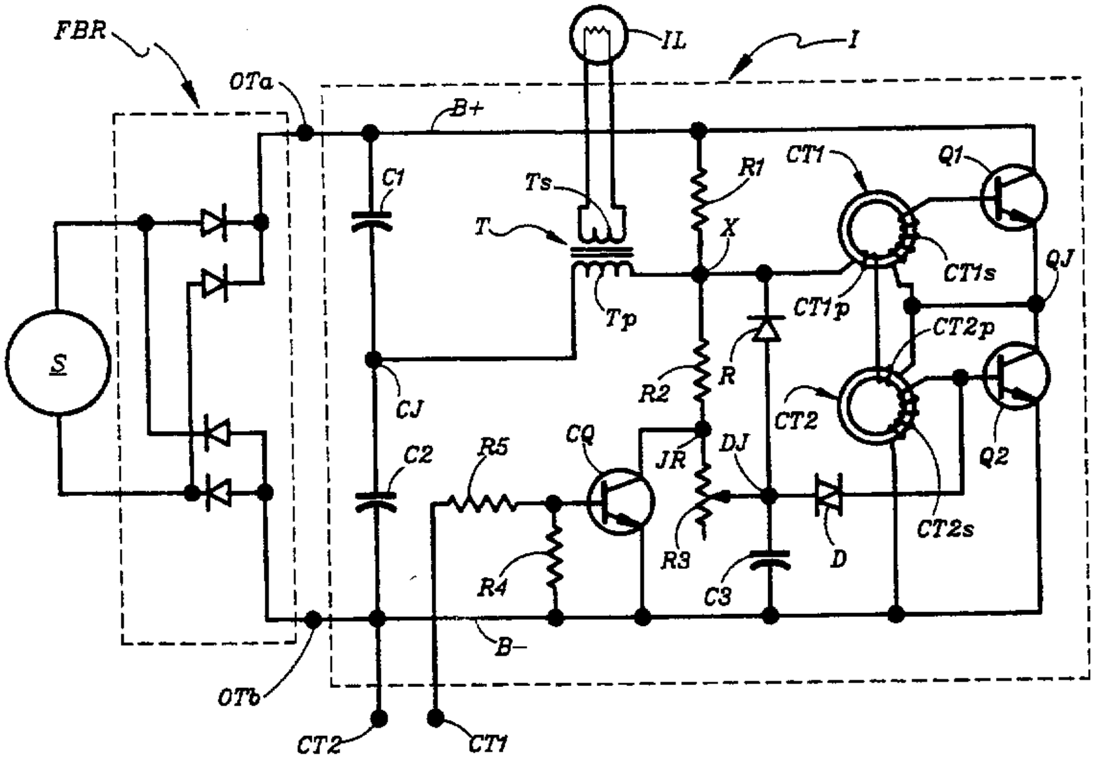
Primary Examiner—Robert J. Pascal

[57] **ABSTRACT**

An inverter is powered by the pulsed DC voltage obtained by unfiltered full-wave rectification of the AC power line voltage provided from an ordinary electric utility power line. The output of the inverter is a 30 kHz squarewave voltage having an instantaneous absolute magnitude that is proportional to that of the AC power line voltage. By way of a step-down voltage transformer, the 30 kHz squarewave inverter output voltage is applied to the filament of a low voltage incandescent lamp.

20 Claims, 2 Drawing Sheets



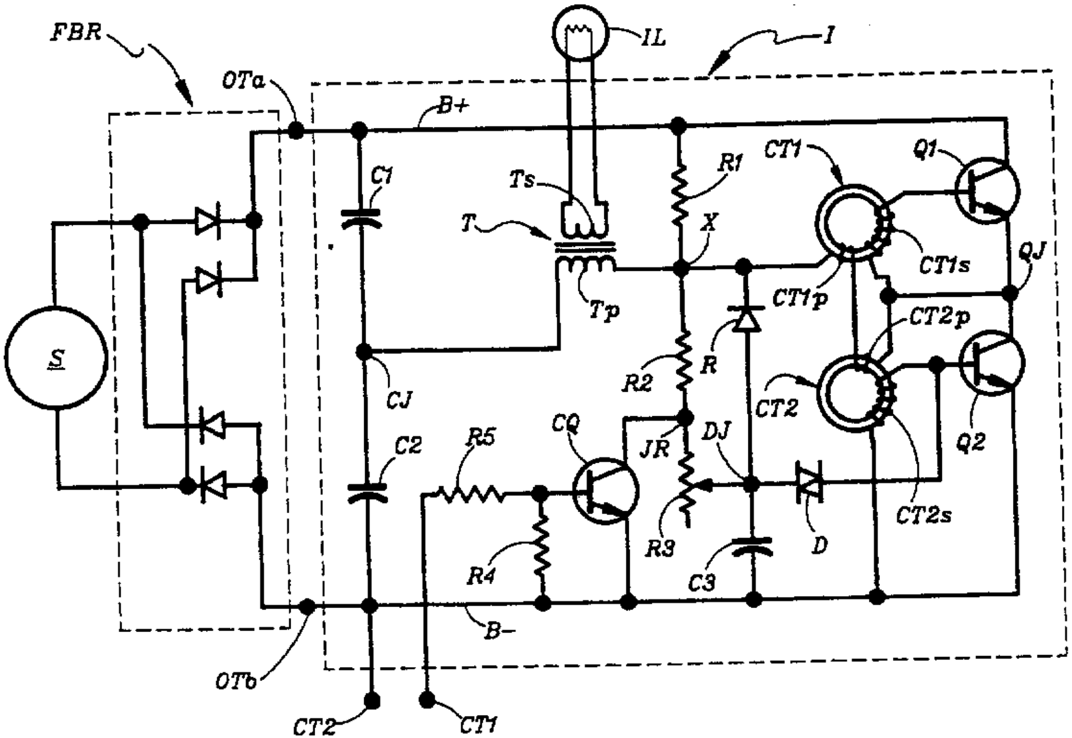


Fig. 1

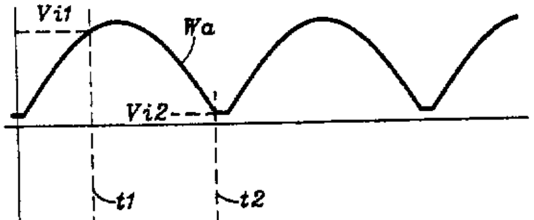


Fig. 2a

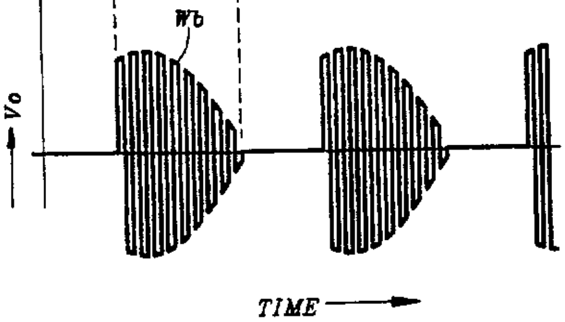


Fig. 2b

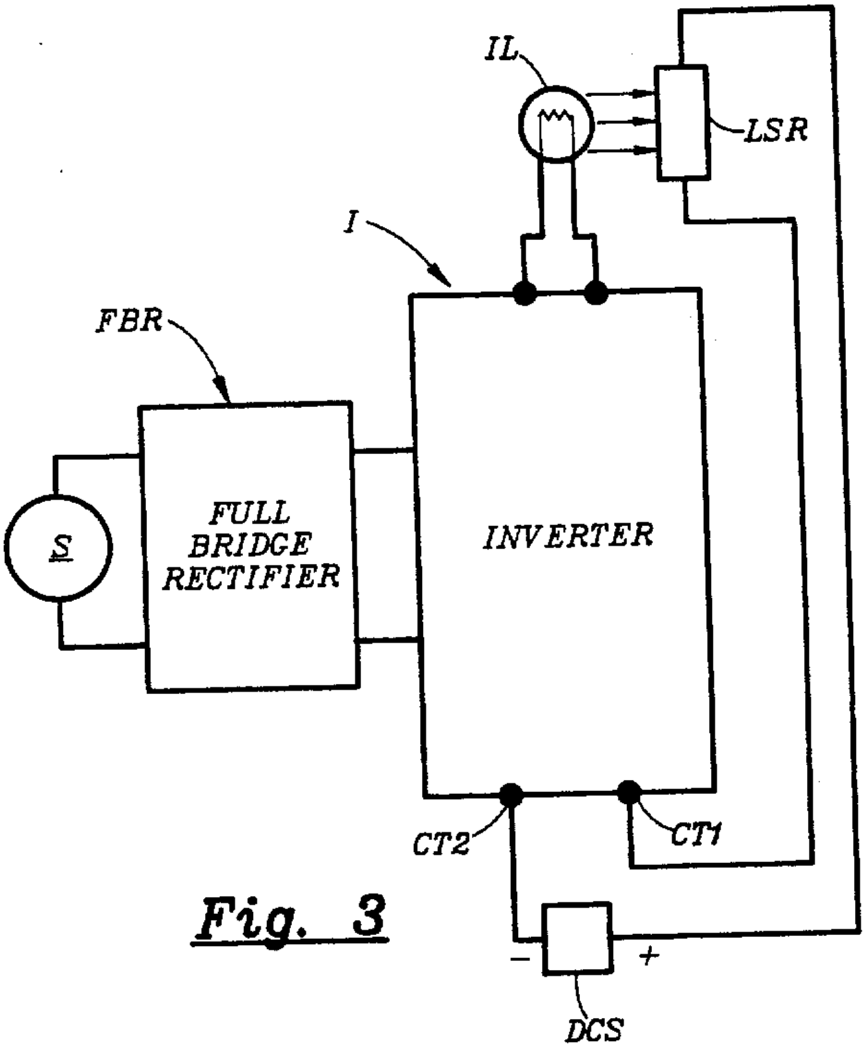


Fig. 3

HIGH-FREQUENCY POWER SUPPLY FOR INCANDESCENT LAMP

RELATED APPLICATIONS

This application is a continuation of Serial No. 07/548,197 filed 07/05/90; which is a Continuation of 06/667,691 filed 11/02/84, abandoned; which was a Continuation-in-Part of Ser. No. 06/487,817 filed 04/22/83, now U.S. Pat. No. 4,506,318.

BACKGROUND OF THE INVENTION

1. Field of Invention

Instant invention relates to power-line-operated inverter-type power supplies operable to power incandescent lamps.

2. Description of Prior Art

Power-line-operated inverter-type power supplies are presently being used in a variety of applications. For instance, such power supplies are frequently being used for powering low-voltage incandescent lamps.

When using such inverter-type power supplies in connection with powering various loads, such as low-voltage incandescent lamps or microwave magnetrons, it is sometimes desirable to be able by way of electrically actuatable means to control the inverter output voltage, thereby providing for control of the power provided to the load. However, to provide cost-effectively for electrically actuatable means to effect control of the output of inverters is not as simple as it might initially appear.

Of course, to achieve such control, one might use an electrically actuatable variable-ratio transformer (Variac) between the power line and the input of the power supply. However, the cost and complexities associated with such an approach would be unacceptably high in most applications.

Or, one might consider the use of a Triac-type voltage control means mounted between the power line and the power supply. However, Triac-type voltage control means simply do not function properly with the kind of input characteristics normally associated with power-line-operated inverter-type power supplies.

Then, there is the possibility of using an inverter-type power supply with a special input circuit that would permit the use of a Triac-type control means; which input circuit would then have to make the inverter power-input-characteristics appear substantially like a resistive load. Even so, however, there is the cost and the electrical inefficiency of the Triac-type control to consider.

SUMMARY OF THE INVENTION

Objects of Invention

An object of the present invention is that of providing a power-line-operated inverter-type power supply having electrically actuatable means to permit output voltage control.

This as well as other objects, features and advantages of the present invention will become apparent from the following description and claims.

BRIEF DESCRIPTION

In its preferred embodiment, subject invention is a power supply adapted to be powered from the regular 60 Hz power line voltage and to provide an output of relatively high-frequency (30 kHz) substantially squarewave voltage. This output voltage is provided by an inverter that is powered by way of the pulsed DC voltage derived from unfiltered full-wave rectification of the 60 Hz power line voltage. Thus, the high-frequency inverter output voltage is pulse-amplitude-modulated at a 120 Hz rate —in correspondence with the pulse-amplitude-modulations of the pulsed DC supply voltage.

The inverter is of a type that has to be triggered into oscillation. However, once triggered, it will continue to oscillate, but only for as long as the instantaneous magnitude its pulsed DC supply voltage exceeds a certain threshold level.

Since the pulsed DC supply voltage falls to zero magnitude between each pulse, the inverter stops oscillating between each pulse. Thus, as long as output voltage is desired, the inverter has to be re-triggered after each pulse of the DC supply voltage.

Inverter triggering is accomplished by a Diac in combination with an RC integrating circuit; which means that—upon each application of a pulse of DC supply voltage—the inverter is triggered into oscillation only after the DC supply voltage has been present for some period of time; the length of this period being determined by the nature of the RC integrating circuit —much in the same way as phase-control is accomplished in an ordinary Triac-type incandescent lamp dimmer.

Connected with the RC integrating circuit is a control transistor, the effective impedance of which can be varied over a wide range by way of an electrical control voltage. With this control voltage having a relatively low magnitude, the inverter is triggered into oscillation quite early in the period of each pulse of the DC supply voltage; whereas, with this control voltage having a relatively large magnitude, no inverter triggering takes place at all.

For in-between magnitudes of the control voltage, inverter triggering takes place at substantially corresponding in-between delays relative to the onset of each DC pulse; which means that the net effective RMS magnitude of the output voltage can be adjusted by adjusting the magnitude of the control voltage.

Thus, by providing a control voltage to a pair of control terminals, the magnitude of the inverter output voltage can be adjusted over a wide range: from a maximum and all the way down to zero output—with a response time equal to half a cycle of the 60 Hz power line voltage.

By sensing the average or RMS magnitude of the inverter output voltage and by providing a control voltage to the control transistor that is effectively proportional to that average or RMS magnitude, output magnitude control can be obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 schematically illustrates the preferred embodiment of the invention, showing an inverter-type power supply adapted to power a low-voltage incandescent lamp.

FIG. 2*a* illustrates the waveform of the DC supply voltage used for powering the inverter; and FIG. 2*b* illustrates the waveform of the inverter's squarewave voltage.

FIG. 3 illustrates the circuit of FIG. 1 arranged with feedback operative to automatically control the RMS magnitude inverter output voltage.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Description of the Drawings

In FIG. 1, a source S of 120Volt/60Hz voltage is connected with full-bridge rectifier FBR. Positive output terminal OTa of rectifier FBR is connected directly with a B+ bus; and negative output terminal OTb of rectifier FBR is connected directly with a B− bus.

Between the B+ bus and the B− bus is connected a series-combination of two capacitors C1 and C2, which two capacitors are connected together at a junction CJ.

Between the B+ bus and the B− bust is also connected a series-combination of two transistors Q1 and Q2.

The secondary winding CT1s of positive feedback current transformer CT1 is connected directly between the base and the emitter of transistor Q1; and the secondary winding CT2s of positive feedback current transformer CT2 is connected directly between the base and the emitter of transistor Q2.

The collector of transistor Q1 is connected directly with the B+bus; the emitter of transistor Q2 is connected directly with the B− bus; and the emitter of transistor Q1 is connected directly with the collector of transistor Q2, thereby forming junction QJ.

The series-connected primary windings CT1p and CT2p are connected directly between junction QJ and a point X; while the primary winding Tp of transformer T is connected between point X and junction CJ.

Transformer T has a secondary winding Ts, which is connected directly with an incandescent lamp IL.

A resistor R1 is connected with its one terminal to the B+bus and with its other terminal to point X. Another resistor R2 is connected between point X and one terminal of a variable resistor R3. The other terminal of R3 is connected to junction DJ, to which junction is also connected one of the terminals of a capacitor C3. The other terminal of C3 is connected to the B- bus.

A Diac D is connected between junction DJ and the base of transistor Q2.

A rectifier R is connected with its anode to junction DJ and with its cathode to junction QJ.

A control transistor CQ is connected with its collector to the junction JR between resistors R2 and R3, and with its emitter to the B− bus. A resistor R4 is connected between the control transistor's base and emitter; and a resistor R5 is connected between a control terminal CT1 and the base of the control transistor. Another control terminal CT2 is connected directly with the B− bus.

The overall inverter is identifed with the letter I.

Actual values and descriptions of the components used in the preferred arrangement in FIG. 1 are listed as follows.

Output of Source S:	120 Volt/60 Hz;
Full Bridge Rectifier FBR:	Four 1N4004's;
Capacitors C1 & C2:	0.47 uF/200 Volt;
Transistors Q1 & Q2:	Motorola MJE13002's;
Transistor CQ:	Motorola MXT3904;
Resistor R1:	33k Ohm/0.25 Watt;
Resistor R2:	100k Ohm/0.25 Watt;
Adjustable Resistor R3:	1.5 Meg Ohm Potentiometer;
Resistor R4:	22k Ohm/0.25 Watt;
Resistor R5:	47k Ohm/0.25 Watt;
Capacitor C3:	22 nF/50 Volt;
Rectifier R:	1N4004;
Diac D:	General Electric ST-2;
Transformers CT1 & CT2:	Wound on Ferroxcube Toroids 213T050 of 3E2A Ferrite Material with two turns of #27 wire for the primary windings and ten turns of #31 wire for the secondary windings;
Transformer T:	Wound on a Ferroxcube 2616 Pot Core of 3C8 Ferrite Material with 95 turns of #27 wire for the primary winding and 20 turns of five twisted strands of #27 wire for the secondary winding;
Incandescent Lamp IL:	12 Volt/25 Watt.

The frequency of inverter oscillation associated with the component values identified above is approximately 30 kHz.

In FIG. 2*a*, the waveform identified as Wa represents the voltage Vi present between the B− bus and the B+ bus as plotted against time t. The magnitude of voltage Vi at the time t1 when the inverter is triggered into oscillation is indicated as Vi1. The magnitude of voltage Vi at the time t2 the inverter drops out of oscillation is indicated as Vi2.

In FIG. 2*b*, the waveform identified as Wb represents the inverter output voltage Vo plotted against time t; which output voltage exists across the secondary winding Ts of transformer T in FIG. 1, and which is the voltage provided to incandescent lamp IL.

FIG. 3 illustrates one particular use of the controllable inverter power supply of FIG. 1. In particular, the circuit arrangement of FIG. 3 is identical with that of FIG. 1 except for having added an automatic feedback control arrangement by way of having placed a light sensitive resistor LSR, such as a selenium semiconductor means, in the proximity of lamp IL and such as to be exposed to part of the light emitted from IL. The light sensitive resistor LSR is connected between the positive terminal of a DC source DCS and control terminal CT1. The negative terminal of DCS is connected directly with control terminal CT2.

DESCRIPTION OF THE OPERATION

The operation of the circuit arrangement of FIG. 1 is described as follows.

Source S represents an ordinary 120Volt/60Hz electric utility power line, the voltage from which is rectified in full-wave fashion by full-bridge rectifier means FBR. Thus, in the absence of filtering means, the voltage present across output terminals OTa and OTb is substantially as depicted in FIG. 2*a*; which voltage is applied directly to the inverter circuit I.

This inverter circuit, which consists of the two series-connected switching transistors Q1 and Q2 in combination with the two positive feedback transformers CT1 and CT2, represents a self-oscillating half-bridge inverter and operates in a manner that is analogous with circuits previously described in published literature, as for instance in U.S. Pat. No. 4,184,128 entitled High Efficiency Push-Pull Inverters.

Since the DC voltage-supply feeding the inverter has no filtering capacitors, it is necessary to provide within the inverter a low impedance return path for the inverter current. Such a low impedance return path is provided by way of the two series-connected capacitors C1 and C2. However, it is necessary that the capacitance values of these capacitors be kept small enough not to represent significant energy-storing capacity in comparison to the amount of energy being drawn by the inverter over a half-cycle of the power line voltage. In this case, with the power drawn being about 25 Watt (which is about 208 milli-Joule per half-cycle of the 60 Hz power line voltage) the energy stored by the two series-connected 0.47 uF capacitors is indeed small in comparison (being only 2.6 milli-Joule at 150 Volt).

In the inverter circuit of FIG. 1, the bases of the transistors are—in terms of DC—shorted to their emitters; which implies that the inverter can not start oscillating by itself. However, by providing but a single brief pulse to the base of transistor Q2, this transistor is caused to conduct momentarily; which momentary conduction puts this one transistor into an amplifying situation; which is enough to trigger the inverter into oscillation—provided, of course, that there is adequate voltage present between the B− bus and the B+ bus.

Once triggered into oscillation, the inverter will continue to oscillate until the voltage between the B− bus and the B+ bus falls to such a low level as to be inadequate for sustaining regenerative feedback. At this point, which is identified as Vi2 in FIG. 2*a*, oscillations cease.

Inverter triggering is accomplished by way of a Diac; which Diac itself is triggered by the voltage on capacitor C3.

The output of the half-bridge inverter circuit is a substantially squarewave 30 kHz AC voltage, which output is provided between point X and junction CJ, and across which output is connected the primary winding of transformer T. The peak-to-peak amplitude of this 30 kHz squarewave voltage is substantially equal to the magnitude of the DC voltage present between the B− bus and the B+ bus; and therefore, as the magnitude of this DC voltage varies, so does the amplitude of the 30 kHz squarewave output voltage.

The incandescent lamp IL is connected directly across the secondary winding Ts of transformer T; which means that the voltage presented to the incandescent lamp is directly proportional to the inverter circuit output voltage.

Being supplied with a pulsed DC voltage similar to that depicted in FIG. 2*a*, the inverter circuit—even if oscillating at some given moment—will cease oscillating when the DC supply voltage falls below a certain minimal level (Vi2 in FIG. 2*a*). Thus, if the inverter is triggered into oscillation at some time during each of the unidirectional sinusoidally-shaped voltage pulses constituting the DC supply voltage, it will cease to oscillate at or near the end of each of these pulses.

In other words, the inverter circuit of FIG. 1 behaves much like a Triac or a thyristor: it can be triggered ON, and will remain ON until the end of the power-cycle—that is, until current flowing to the load falls below a certain threshold level. And, just like a thyristor, it can be triggered at substantially any point within the power-cycle; which means that it can be phase-controlled in a manner analogous to that of a thyristor.

In yet other words, the RMS or average magnitude of the voltage provided to the incandescent lamp can be controlled over a wide range simply by controlling the timing of the inverter trigger point (t1 in FIG. 2).

Triggering of the inverter circuit is accomplished essentially the same way as is the triggering of a Triac, and phase control is accomplished in the same manner.

In FIG. 1, resistors R2 and R3 in combination constitute a resistance means through which capacitor C3 is charged. By adjusting the magnitude of the combined resistance, the time to charge capacitor C3 is similarly adjusted; which implies that the phase-point (i.e., t1 in FIG. 2*a*) at which the inverter is triggered into oscillation is correspondingly adjusted.

The purpose of rectifier R is that of making sure that capacitor C3 gets fully discharged after the inverter is triggered into oscillation; which implies that this capacitor will start each new power cycle in a fully discharged condition, thereby assuring time-consistent triggering.

The reason for having R2 as a resistor physically separate from R3 is that of preventing the voltage at point X from being applied directly to capacitor C3, which could provide for a situation of actually preventing triggering from taking place.

The purpose of resistor R1, the resistance value of which is quite small in comparison with that of R2 and R3 combined, is that of making sure that there is enough voltage at junction CJ (relative to the B− bus) to permit the inverter circuit to be triggered into oscillation.

The function of control transistor CQ is that of providing for an electrically actuatable means by which the triggering of Diac D can be controlled. When there is no control voltage provided between control terminals CT1 and CT2, transistor CQ is non-conducting, and the trigger circuit (which consists of resistors R2 and R3, capacitor C3 and Diac D) will operate as if CQ is non-present. However, as an increasing positive voltage is provided to control terminal CT1, CQ will eventually start to conduct and thereby to shunt charging current away from capacitor C3. The more positive current that is provided into the base of CQ, the more charging current is shunted away from C3. Eventually, with a relatively high positive voltage provided at control terminal CT1, CQ gets so much base current that its shunting effect entirely prevents C3 to charge to a voltage high enough to provide triggering pulses.

Thus, by providing a unidirectional control voltage between control terminals CT1 and CT2—with the positive terminal of the control voltage being connected with CT1—electrically actuatable inverter trigger control results; which implies that the 30 kHz inverter output voltage can be electrically switched ON and/or OFF, as well as continuously controlled in terms of magnitude.

The arrangement of FIG. 3 demonstrates one way in which the control capability of the circuit of FIG. 1 can be put to use. The light output of lamp IL affects inverter triggering in such a way that increased light output will cause reduction in the RMS magnitude of the 30 kHz voltage output; which implies that—since light output is proportional to the RMS magnitude of the lamp voltage—the RMS magnitude of the lamp voltage will tend to remain constant even if the RMS magnitude of the power line voltage might change.

Another application in which the power supply of FIG. 1 can advantageously be used is as an electrically controllable source of power for the magnetron in a microwave oven—i.e., where the load would be a magnetron and not an incandescent lamp. In such an application, it would be desirable to have an electronic programming means be able to control the amount of power supplied to the microwave magnetron; which, of course, can be readily accomplished by way of having this programming means provide appropriate control voltages to control terminals CT1 and CT2.

Otherwise, the following comments are offered.

a) The concept of feeding an inverter with a pulsed DC voltage and to have its oscillations phase controlled (in relationship to the phasing of the DC pulses) is not limited to be used with a half-bridge inverter circuit. Most any type of self-oscillating inverter circuit may be used, the chief criterion being that the inverter circuit must be of such a nature as to have to be triggered into oscillation.

b) To achieve a reasonably wide range of control of RMS output voltage, it is important that the inverter be capable of sustained self-oscillation even at relatively low levels of DC supply voltage. In the circuit of FIG. 1, stable inverter self-oscillation is sustained down to a DC supply voltage of about 20 Volt; below which voltage oscillations abruptly cease.

It is believed that the present invention and its several attendant advantages and features will be understood from the preceeding description. However, without departing from the spirit of the invention, changes may be made in its form and in the construction and interrelationships of its component parts, the form herein presented merely representing the preferred embodiment.

What is claimed is:

1. An arrangement comprising:

a source providing a relatively low-frequency AC power line voltage at a pair of power line terminals;

incandescent lamp having a pair of lamp terminals; and

power supply connected between the power line terminals and the lamp terminals; the power supply being operative to provide a relatively high-frequency AC lamp voltage across the lamp terminals; the AC lamp voltage having: (i) a fundamental frequency at least twenty times higher than that of the AC power line voltage (ii) numerous complete relatively short half-cycles during each complete relatively long half-cycle of the AC power line voltage, with each of the numerous complete relatively short half-cycles having a peak magnitude; and (iii) the absolute value of the peak magnitude of the numerous complete relatively short half-cycles varying in time such as to be proportional to the absolute value of the instantaneous peak magnitude of the AC power line voltage, at least during a substantial portion of each relatively long half-cycle of the AC power line voltage.

2. The arrangement of claim 1 wherein said substantial portion represents more than half of the total half-period of each cycle of the AC power line voltage.

3. The arrangement of claim 1 wherein the RMS magnitude of the AC lamp voltage is substantially lower than that of the AC power line voltage.

4. The arrangement of claim 1 wherein the fundamental frequency of the AC lamp voltage is equal to, or higher than, about 10 kHz.

5. The arrangement of claim 1 wherein the AC lamp voltage is a squarewave voltage amplitude-modulated at a frequency equal to twice the fundamental frequency of the AC power line voltage.

6. The arrangement of claim 1 wherein the power supply includes: (i) rectifier connected with the power line terminals and operative to provide a DC voltage at a set of DC terminals, the DC voltage having an absolute instantaneous magnitude about equal to that of the AC power line voltage; and (ii) inverter means connected between the DC terminals and the lamp terminals.

7. An arrangement comprising:

a source providing an AC power line voltage at a pair of power line terminals;

incandescent lamp having a pair of lamp terminals; and

power supply connected between the power line terminals and the lamp terminals; the power supply being operative to provide an AC lamp voltage across the lamp terminals; the AC lamp voltage having: (i) a fundamental frequency significantly higher than that of the AC power line voltage; and (ii) at least during a substantial portion of each half-cycle of the AC power line voltage, an instantaneous absolute magnitude proportional to that of the AC power line voltage.

8. The arrangement of claim 7 wherein the RMS magnitude of the AC lamp voltage is substantially lower than that of the AC power line voltage.

9. The arrangement of claim 7 wherein the AC lamp voltage is a squarewave voltage having a fundamental frequency equal to or higher than about 10 kHz and being amplitude-modulated at a frequency equal to twice the fundamental frequency of the AC power line voltage.

10. The arrangement of claim 7 wherein said substantial portion represents over half of the total half-period of each cycle of the AC power line voltage.

11. The arrangement of claim 7 wherein the power supply includes: (i) a rectifier connected with the power line terminals and operative to provide a DC voltage at a set of DC terminals, the DC voltage having an absolute instantaneous magnitude about equal to that of the AC power line voltage; and (ii) an inverter means connected between the DC terminals and the lamp terminals.

12. An arrangement comprising:

a source providing AC power line voltage at a pair of power line terminals;

an incandescent lamp having a pair of lamp terminals;

a rectifier connected with the power line terminals and operative to provide at a pair of DC terminals an unfiltered DC voltage having an absolute instantaneous magnitude about equal to that of the AC power line voltage; and

an inverter connected between the DC terminals and the lamp terminals; the inverter being powered by the unfiltered DC voltage and operative to provide a lamp voltage across the lamp terminals; the lamp voltage being an alternating voltage of fundamental frequency substantially higher than that of the AC power line voltage.

13. The arrangement of claim 12 wherein: (i) the lamp voltage has a peak-to-peak absolute magnitude that varies in time at a frequency equal to twice that of the AC power line voltage; (ii) the peak-to-peak absolute magnitude has a maximum value that re-occurs at a rate equal to twice the frequency of the AC power line voltage; and (iii) the lamp voltage has an absolute instantaneous magnitude that never exceeds the absolute instantaneous magnitude of a sinusoidal voltage with frequency equal to that of the AC power line voltage and peak-to-peak absolute magnitude equal to said maximum value.

14. The arrangement of claim 13 wherein the lamp voltage is a squarewave voltage of frequency equal to, or higher than, about 10 kHz.

15. The arrangement of claim 13 wherein the alternating voltage: (i) has a frequency equal to, or higher than, about 10 kHz; (ii) has a peak-to-peak absolute magni-

tude that is periodically modulated in time at a frequency equal to twice that of the AC power line voltage; and (iii) has a peak-to-peak absolute magnitude that is, at least during a substantial part of each half-cycle of the AC power line voltage, proportional to the instantaneous absolute magnitude of the AC power line voltage.

16. The arrangement of claim **13** wherein: (i) the lamp voltage consists of periodic bursts of high-frequency alternating voltage; (ii) the high-frequency alternating voltage having a frequency of about 10 kHz or higher; and (iii) the periodic bursts occur at a rate equal to twice the frequency of the AC power line voltage.

17. An arrangement comprising:

a source providing AC power line voltage at a pair of power line terminals;

an incandescent lamp having a pair of lamp terminals;

a power supply connected between the power line terminals and the lamp terminals; the power supply being operative to provide a lamp voltage across the lamp terminals; the lamp voltage consisting of periodic bursts of high-frequency alternating voltage; the high-frequency alternating voltage having a fundamental frequency equal to, or higher than, about 10 kHz; each burst of high-frequency alternating voltage having a certain maximum peak-to-peak absolute magnitude; the absolute instantaneous magnitude of the lamp voltage never exceeding the absolute instantaneous magnitude of a substantially sinusoidal voltage with frequency equal to that of the AC power line voltage and peak-to-peak absolute magnitude equal to said maximum peak-to-peak absolute magnitude.

18. The arrangement of claim **17** wherein the periodic bursts of high-frequency alternating voltage occur at a rate equal to twice the frequency of the AC power line voltage.

19. The arrangement of claim **18** wherein the power supply includes: (i) rectifier connected with the power line terminals and operative to provide a DC voltage at a set of DC terminals, the DC voltage having an absolute instantaneous magnitude about equal to that of the AC power line voltage; and (ii) inverter means connected between the DC terminals and the lamp terminals.

20. The arrangement of claim **18** wherein the high-frequency alternating voltage is a squarewave voltage.

* * * * *

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US005159245A

United States Patent [19]

Nilssen

[11] **Patent Number: 5,159,245**

[45] **Date of Patent: Oct. 27, 1992**

[54] **TRACK LIGHTING SYSTEM FOR 277 VOLT POWER LINE**

[76] Inventor: **Ole K. Nilssen**, Caesar Dr., Rte. 5, Barrington, Ill. 60010

[21] Appl. No.: **789,800**

[22] Filed: **Nov. 12, 1991**

Related U.S. Application Data

[63] Continuation of Ser. No. 511,951, Apr. 16, 1990, abandoned, which is a continuation of Ser. No. 889,746, Jul. 28, 1986, abandoned, which is a continuation-in-part of Ser. No. 667,691, Nov. 2, 1984, which is a continuation-in-part of Ser. No. 487,817, Apr. 22, 1983, Pat. No. 4,506,318.

[51] **Int. Cl.**^{5} **H05B 37/00**

[52] **U.S. Cl.** **315/206**; 315/210; 315/DIG. 7

[58] **Field of Search** .... 315/210, 206, 70, 312, 315/205, 224, DIG. 4:DIG. 5, DIG. 7; 339/21 R, 22 R; 363/132

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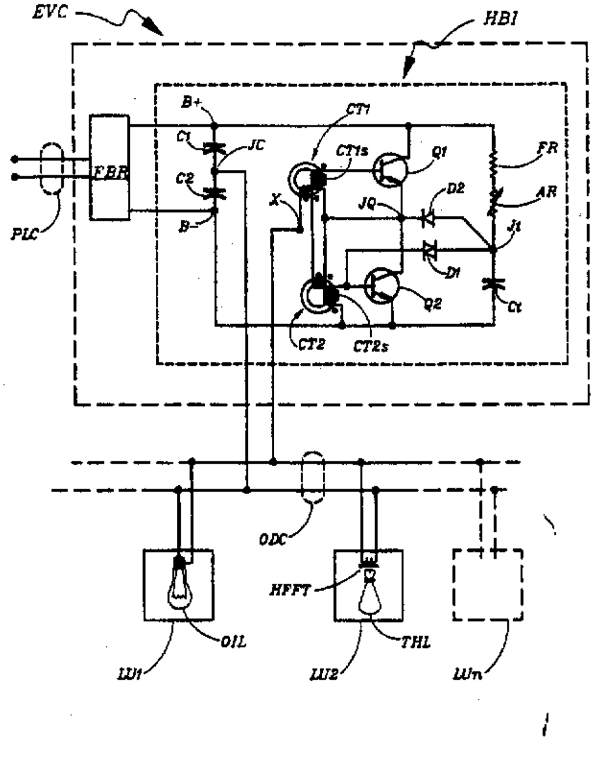
Primary Examiner—Eugene R. LaRoche
Assistant Examiner—A. Zarabian

[57] **ABSTRACT**

In a track lighting system for a 277 volt power line, proper voltage for powering 120 volt incandescent lamps is obtained by way of an integral electronic transformer-less voltage conditioner. Thus, ordinary 120 volt incandescent lamps can be used directly in the power tracks of this track lighting system, the voltage conditioner includes a full-bridge rectifier providing an unfiltered DC supply voltage consisting of sinusoidally-shaped unidirectional voltage pulses having an RMS magnitude of 277 volt. This DC supply voltage is provided to a half-bridge inverter; which, as long as it is in operation, provides a high-frequency output voltage of RMS magnitude equal to half of the RMS magnitude of the DC supply voltage. However, by arranging for the inverter to operate only during part of each of the DC voltage pulses provided from the full-bridge rectifier, the RMS magnitude of the inverter's output voltage can readily be arranged to have an RMS magnitude somewhat lower than half of 277 volt —such as 120 volt, since the major part of the voltage-magnitude-reduction is accomplished by way of the half-bridge inverter action itself—which action naturally provides for a halving of the voltage magnitude—the resulting power factor of the power drawn by the track lighting system from the 277 volt power line is excellent.

17 Claims, 2 Drawing Sheets



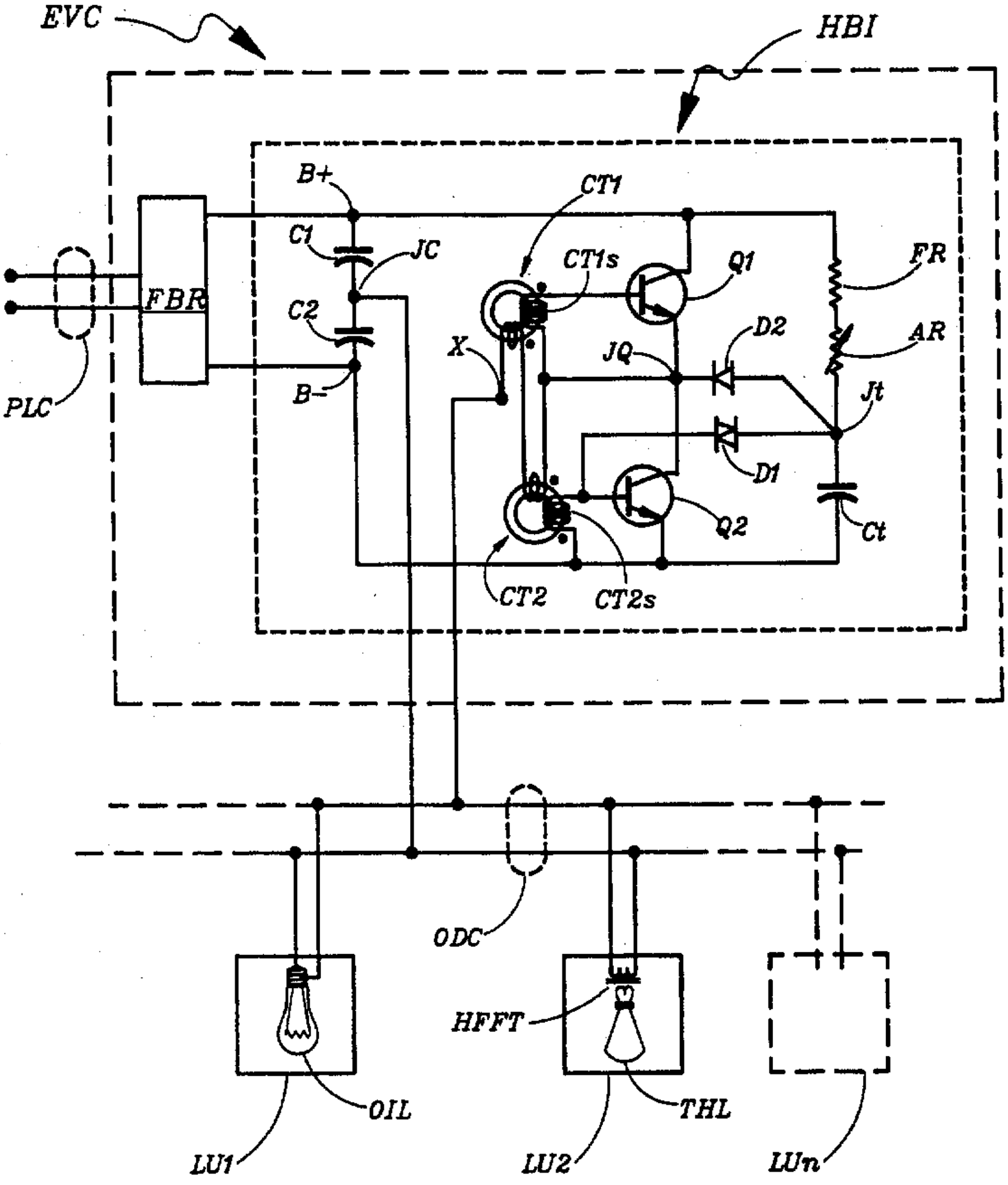

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Fig. 1

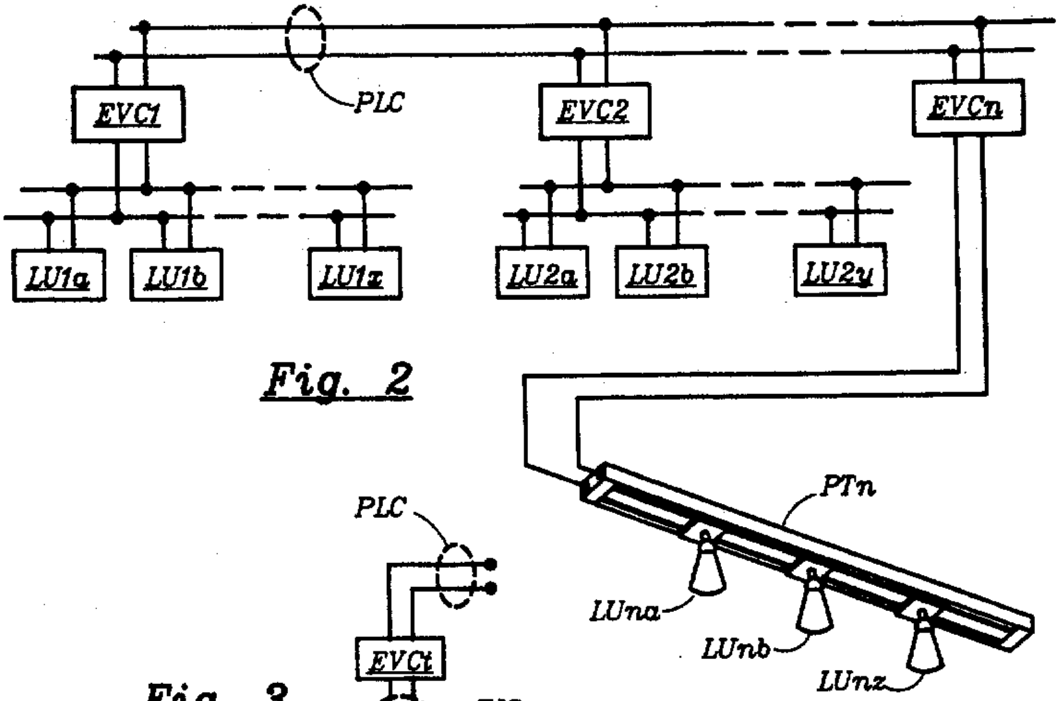

Fig. 2

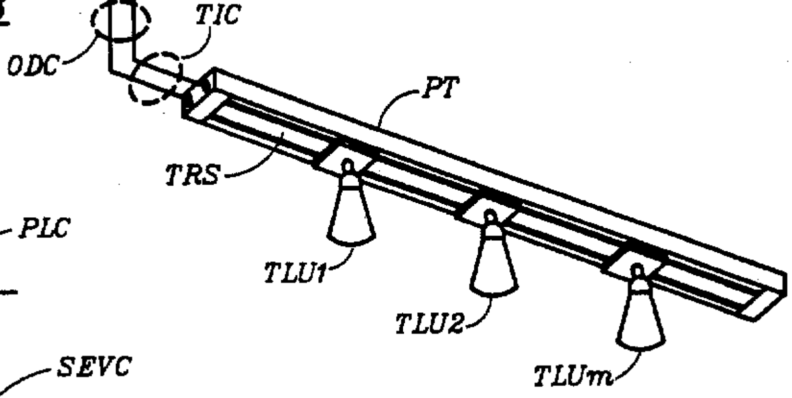

Fig. 3

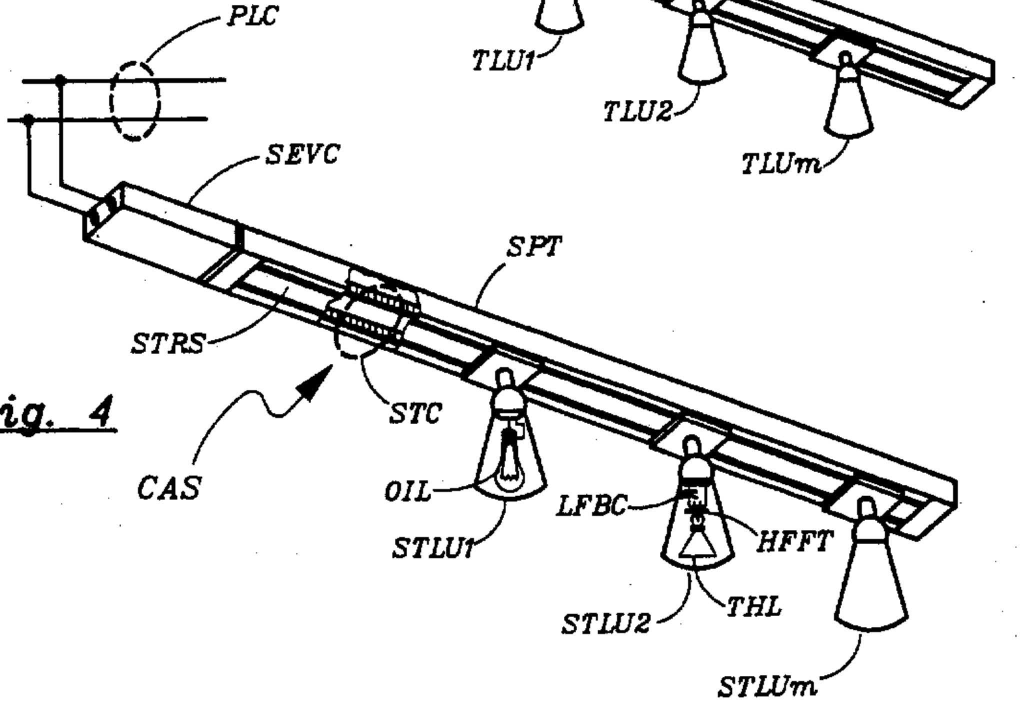

Fig. 4

TRACK LIGHTING SYSTEM FOR 277 VOLT POWER LINE

This is a continuation of Ser. No. 06/511,951 filed Apr. 16, 1990, now abandoned; which was a continuation of Ser. No. 06/889,745 filed Jul. 28, 1986, now abandoned; which was a continuation-in-part of Ser. No. 06/667,691 filed Nov. 2, 1984; which was a continuation-in-part of Ser. No. 06/487,817 filed Apr. 22, 1983, now U.S. Pat. No. 4,506,318.

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to a track lighting system adapted to be powered from a 277 Volt power line, yet—by way of an electronic voltage conditioner—operative to provide 120 Volt voltage on the power track, thereby permitting the use therein of ordinary 120 Volt incandescent lamps.

2. Prior Art

For reasons of cost-effectivity, electric power distribution in commercial buildings is preferably accomplished by way of a 277 Volt distribution voltage.

However, if a track lighting system is installed, it is necessary to use a distribution voltage of 120 Volt RMS magnitude; otherwise, it would be necessary to use very special incandescent light bulbs in the power tracks and/or to provide a very special voltage-magnitude-transformation means between the 277 Volt power line and the power tracks.

In commercial lighting systems where the predominant lighting means are gas discharge lamps, the distribution voltage or choice is 277 Volt. However, in combination with a gas discharge lighting system it is frequently necessary to provide for incandescent track lighting as well. Yet, available incandescent lamps are designed for operation on 120 Volt; which implies the necessity in such situations of providing for some sort of voltage-magnitude-transformation means. In present 277 Volt installations, voltage-magnitude-transformation means for incandescent lamps are provided in the form of 60 Hz voltage step-down transformers. However, within economically realistic limits, such transformers are highly inefficient and very heavy.

SUMMARY OF THE INVENTION

Objects of the Invention

An object of the present invention is that of providing a track lighting system operable to be powered by a relatively high-magnitude voltage, such as 277 Volt, yet being cost-effectively operative to properly power lamps designed to operate on a relatively low-magnitude voltage, such as 12 or 120 Volt.

More specifically, an object of the present invention is that of providing a track lighting system powered from a 277 therein of incandescent lamps designed for operation on 120 Volt.

These, as well as other objects, features and advantages of the present invention will become apparent from the following description and claims.

BRIEF DESCRIPTION

In its preferred embodiment, the present invention is a track lighting system adapted to be powered from a 277 Volt AC power line and operative to provide on its power tracks proper voltage for powering ordinary 120 Volt incandescent lamps.

The 120 Volt power track voltage is obtained by way of an integral electronic transformer-less voltage conditioner. This voltage conditioner includes a full-bridge rectifier providing an unfiltered DC supply voltage consisting of sinusoidally-shaped unidirectional voltage pulses having an RMS magnitude of 277 Volt. In fact, the instantaneous magnitude of this DC supply voltage is substantially equal to that of the 277 Volt AC voltage.

The DC supply voltage is provided to a half-bridge inverter; which, as long as it is in operation, provides a high-frequency (i.e., about 30 kHz) output voltage of RMS magnitude equal to half that of the DC supply voltage. By arranging for the inverter to operate only during part of each of the unidirectional voltage pulses provided from the full-bridge rectifier, the RMS magnitude of the inverter's output voltage can readily be adjusted to have an RMS magnitude somewhat lower than half of 277 Volt—such as 120 Volt.

Since the major part of the voltage-magnitude-reduction is accomplished by way of the half-bridge inverter action itself—which action naturally provides for a halving of the voltage magnitude of the inverter's AC output voltage as compared with that of its DC supply voltage—the resulting power factor of the power drawn from the 277 Volt power line is excellent: better than 85%. Moreover, the overall efficiency is very much better than that attainable with ordinary 60 Hz transformers: on the order of 95% or better.

Since the frequency of the 120 Volt power track voltage is relatively high (i.e., about 30 kHz), it becomes cost-effectively feasible to use 12 Volt Tungsten-Halogen lamps in the system's track lighting units. The 12 Volt RMS required for properly powering these Tungsten-Halogen lamps is obtained by way of very compact and highly efficient high-frequency ferrite transformer means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 provides a basic electrical circuit diagram of the preferred embodiment of the invention.

FIG. 2 provides a schematic diagram of a larger-scale lighting system constructed in accordance with the present invention.

FIG. 3 illustrates a first track lighting system constructed in accordance with the present invention.

FIG. 4 illustrates a second track lighting system constructed in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Details of Construction

FIG. 1 schematically illustrates the electrical circuit arrangement of subject track lighting system.

An electronic voltage conditioner EVC is connected with power line conductors PLC of a 277 Volt/60 Hz power line, and provides an output of 120 Volt/30 kHz across a pair of output and distribution conductors ODC.

A number of 120 Volt lighting units LU1, LU2 . . . LUn are connected with output and distribution conductors ODC.

Lighting unit LU1 consists of an ordinary 120 Volt incandescent lamp OIL, and lighting unit LU2 consists of a 12 Volt Tungsten-Halogen lamp THL connected with conductors ODC by way of a high-frequency ferrite transformer HFFT.

Within electronic voltage conditioner EVC, a full-bridge rectifier FBR is connected with the 277 Volt/60 Hz power line conductors (PLC) and provides its rectified output across a B+ bus and a B− bus, with the B+ bus being of positive polarity.

A half-bridge inverter HBI is connected with the B+ bus and the B− bus; and the 120 Volt/30 kHz output from this inverter is provided across output and distribution conductors ODC.

Within half-bridge inverter HBI, connected between the B+ bus and a junction JC, is a first capacitor C1; and connected between junction JC and the B− bus is a second capacitor C2.

Connected with the B+ bus and a junction JQ are the collector and the emitter, respectively, of a first transistor Q1; and, similarly, connected with junction JQ and the B− bus are the collector and the emitter, respectively, of a second transistor Q2.

Secondary winding CT1s of saturable current transformer CT1 is connected between the base and the emitter of transistor Q1; and secondary winding CT2s of saturable current transformer CT2 is connected between the base and the emitter of transistor Q2. The primary windings of current transformers CT1 and CT2 are connected in series between a point X and junction JQ.

A fixed resistor FR is connected in series with an adjustable resistor AR to form a series-combination; and this series-combination is connected between the B+ bus and a junction Jt. A capacitor Ct is connected between junction Jt and the Bbus; a Diac D1 is connected between junction Jt and the base of transistor Q2; and a diode D2 is connected with its anode to junction Jt and with its cathode to junction JQ.

Output and distribution conductors ODC are connected between junction JC and point X.

FIG. 2 illustrates a situation where a plurality of electronic voltage conditioners EVC1, EVC2 . . . EVCn are each connected with a single pair of 277 Volt/60 Hz power line conductors PLC. Connected with EVC1 are lighting units LU1a, LU1b . . . LU1x; connected with EVC2 are lighting units LU2a, LU2b . . . LU2y; and connected with EVCn by way of power track PTn are lighting units LUna, LUnb . . . LUnz.

FIG. 3 illustrates more specifically a track lighting system wherein an electronic voltage conditioner EVCt is powered from 277 Volt/60 Hz power line conductors PLC and provides a 120 Volt/30 kH output by way of a pair of output and distribution conductors ODC to a pair of track input conductors TIC to a power track PT having a track receptacle slot TRS, into which track receptacle slot are inserted a number of track lighting units TLU1, TLU2 . . . TLUm.

FIG. 4 illustrates an arrangement wherein a special electronic voltage conditioner SEVC has been integrated with a special power track SPT, thereby to render this special power track operable to connect directly with 277 Volt/60 Hz power line conductors PLC and to provide 120 Volt/30 kHz on its special track conductors STC; which special track conductors are shown in cut-away section CAS of the special power track. Inserted into and held by a special track receptacle slot STRS of this special power track are special track lighting units STLU1, STLU2 . . . STLUm. Special track lighting unit STLU1 comprises an ordinary 120 Volt incandescent lamp OIL adapted to connect directly with special track conductors STC. Special track lighting unit STLU2 comprises a 12 Volt Tungsten-Halogen lamp THL connected with special track conductors STC by way of high-frequency ferrite transformer HFFT and low-frequency blocking capacitor LFBC.

Details of Operation

In FIG. 1, the 277 Volt/60 Hz power line voltage provided from the power line conductors (PLC) are full-wave-rectified in the full-wave rectifier (FWR) and provided to the B+/B− terminals in the form of unfiltered full-wave-rectified 277 Volt/60 Hz voltage. Thus, the DC voltage provided between the B+ bus and the B− bus consists of unidirectional sinusoidally-shaped voltage pulses occurring at the rate of 120 per second. In other words, the instantaneous magnitude or the DC supply voltage is substantially equal to the instantaneous absolute magnitude of the 277 Volt/60 Hz power line voltage.

Detailed operation of the half-bridge inverter (HBI) is explained in U.S. Pat. No. 4,506,318 to Nilssen.

In particular, the two series-connected transistors (Q1/Q2) in combination with the two series-connected capacitors (C1/C2) and the two feedback current transformers (CT1/CT2) act as a 30 kHz self-oscillating half-bridge inverter; which inverter is powered by the unfiltered full-wave-rectified 277 Volt/60 Hz power line voltage.

This inverter is of a type that needs to be triggered into oscillation, and that drops out of oscillation whenever the B+ voltage falls below a given relatively low magnitude.

Hence, near the end of each individual pulse of the full-wave-rectified 277 Volt/60 Hz DC supply voltage, the inverter ceases oscillation; and it then has to be re-triggered to start oscillation again.

The time constant associated with resistors FR and AR as combined with capacitor Ct can be adjusted such as to cause the capacitor to reach a voltage-magnitude high enough to cause the Diac (D1) to trigger at substantially any position during each individual pulse of the unfiltered DC voltage. By adjusting the resistance value of AR, the trigger point can be adjusted over a wide range; which means that the RMS magnitude of the inverter's output voltage can be correspondingly adjusted to nearly any RMS value lower than that present when triggering occurs at the very beginning of each pulse of the DC supply voltage.

It is noted that the instantaneous absolute magnitude of the voltage provided at the inverter's output—i.e., the output provided between junction JC and point X—is substantially equal to half that of the DC supply voltage. Thus, as long as it is oscillating, the half-bridge inverter (HBI) acts to reduce the RMS magnitude of the DC supply voltage by a factor of two.

In other words, since the RMS magnitude of the DC supply voltage is substantially equal to that of the 277 Volt/60 Hz power line voltage, as long as the inverter indeed oscillates, the RMS magnitude of the output of the half-bridge inverter (HBI) is substantially equal to half that of the 277 Volt/60 Hz power line voltage; which is to say that it will be equal to about 138.5 Volt as long as the inverter oscillates in a substantially continuous mode.

However, by suitably delaying the point at which the inverter is triggered into oscillation at the beginning of each sinusoidally-shaped unidirectional voltage pulse of the DC supply voltage, a further reduction of the RMS magnitude of the inverter's output can readily be attained.

Specifically, by delaying the trigger point approximately 65 degrees, the net RMS magnitude of the inverter output voltage will be reduced to approximately 120 Volt.

The net overall power factor resulting from this amount of phase delay is about 88%; which is to say that to reduce the RMS magnitude from 138.5 Volt (half of 277 Volt) to 120 Volt (by way of phase-control similar to that used in a Triac-type light dimmer) results in a power factor of about 88%.

Additional Comments

a) In view of the explanation of the operation of the arrangement of FIG. 1, the operation of the arrangements illustrated in FIGS. 2–4 is substantially self-explanatory.

b) Since the frequency of the output voltage from the halfbridge inverter (30 kHz) is so very much higher than the 60 Hz on the power line, any power transformer for changing the RMS magnitude of the 120 Volt/30 kHz inverter output voltage becomes very small and inexpensive. This particular fact is taken into account by showing one of the lighting units (LU2 of FIG. 1 or STLU2 of FIG. 4) as having a 12 Volt Tungsten-Halogen lamp powered by way of a 30 kHz 120 Volt-to-12 Volt ferrite transformer.

c) Of course, the reduction from 277 Volt RMS to 120 Volt RMS may be accomplished directly by way of a light-dimming-type approach—such as by using a Triac. However, the resulting power factor would then be less than 44% or so (i.e., equal to the ratio of 120 to 277); which generally would be considered unacceptably low.

d) With a distribution voltage of 240 Volt RMS magnitude, there is no need for RMS magnitude-reduction beyond that which is attained directly by way of the half-bridge inverter; in which case the resulting power factor will be just about 100%.

e) With an efficiency of about 99% for the full-bridge rectifier (FBR) and about 98% for the half-bridge inverter (HBI), the overall output-to-input efficiency of the electronic voltage conditioner (EVC) is about 97%.

f) Since the efficiency is so very high, and since no power transformer is used, the overall size of the complete electronic voltage conditioner (EVC) can be very small: small enough to be integrally included as element SEVC of the special power track (SPT) in the special track lighting system of FIG. 4.

g) If an overall power factor of 88% should in some situations prove to be inadequate, increased power factor can readily be attained by providing for a very small 30 kHz autotransformer between the output of the half-bridge inverter (HBI) and the output/distribution conductors (ODC), and arranged such as to yield a slightly reduced-magnitude voltage to the ODC.

h) By providing for light-responsive feedback to control the firing angle of the half-bridge inverter, it is readily possible to maintain constant the RMS magnitude provided to the output/distribution conductors (ODC) regardless of significant changes in the RMS magnitude of the 277 Volt/60 Hz power line voltage.

i) It is noted that the capacitance of capacitors C1 and C2 of FIG. 1 need only be adequate to provide for a fairly low impedance path for currents of 30 kHz frequency; which implies that they can be very compact of size.

j) The fact that a half-bridge inverter operates in such manner as to provide an output voltage having an instantaneous magnitude that is substantially equal to half that of the DC supply voltage, might be understood by recognizing that in such an inverter the load means is connected between a center-tap of the DC supply (i.e., the junction JC between capacitors C1 and C2 in FIG. 1) and a point (X in FIG. 1)) that is alternatingly connected with the B+ bus and the B− bus.

k) It is believed that the present invention and its several attendant advantages and features will be understood from the preceeding description. However, without departing from the spirit of the invention, changes may be made in its form and in the construction and interrelationships of its component parts, the form herein presented merely representing the presently preferred embodiment.

I claim:

1. A track lighting system comprising:

a source providing a low-frequency AC voltage at a pair of power line terminals; the low-frequency AC voltage having a fundamental period consisting of two half-periods;

a power track having a pair of track conductors as well as a receptacle slot operable to receive and hold track lighting units with socket terminals operative to make electrical contact with the track conductors; and

voltage conditioning means connected between the power line terminals and the truck conductors; the voltage conditioning means being operative, but only during a part of each half-period, to provide a high-frequency AC voltage to the track conductors; the fundamental frequency of the high-frequency AC voltage being substantially higher than that of the low-frequency AC voltage; all during said part of each half-period, the instantaneous absolute magnitude of the high-frequency AC voltage being substantially equal to half that of the low-frequency AC voltage;

whereby the RMS magnitude of the high-frequency AC voltage is less than half that of the low-frequency AC voltage.

2. The track lighting system of claim 1 wherein the voltage conditioning means includes a full-wave rectifier means as well as a half-bridge inverter means.

3. The track lighting system of claim 1 wherein the magnitude of the low-frequency AC voltage is about 277 Volt RMS and the magnitude of the high-frequency AC voltage is about 120 Volt RMS.

4. The track lighting system of claim 1 wherein, during said part of each half-cycle, intermittent periodic ohmic contact is made between one of the power line terminals and one of the track conductors.

5. The track lighting system of claim 1 wherein, during said part of each half-cycle, current may flow directly between one of the power lien terminals and one of the track conductors.

6. The track lighting system of claim 11 wherein the waveform of the high-frequency AC voltage is squarewave.

7. A track lighting system comprising:

a source providing a low-frequency AC voltage at a pair of power line terminals;

a power track having a pair of track conductors as well as a receptacle slot operable to receive and hold track lighting units with socket terminals operative to make electrical contact with the track conductors; and

voltage conditioning mans connected between the power line terminals and the track conductors; the voltage conditioning means being operative to provide a high-frequency AC voltage to the track conductors; the fundamental frequency of the high-frequency AC voltage being very much higher than that of the low-frequency AC voltage; the high-frequency AC voltage being amplitude-modulated, thereby varying periodically between being of a relatively low magnitude and being of a relatively high magnitude; the relatively high magnitude being several times larger than the relatively low magnitude.

8. The track lighting system of claim 7 wherein the high-frequency AC voltage is a squarewave voltage.

9. The track lighting system of claim 7 wherein, during at least a part of each fundamental period of the low-frequency AC voltage, intermittent periodic ohmic contact is made between one of the power line terminals and one of the track conductors.

10. The track lighting system of claim 7 wherein, during at least a part of each fundamental period of the low-frequency AC voltage, current flow directly between one of the power line terminals and one of the track conductors.

11. The track lighting system of claim 7 wherein: (i) a track lighting unit is indeed connected with the track conductors: (ii) the voltage conditioner means includes a full-bridge reactifier connected directly with the power line terminals; and (iii) the voltage conditioners means draws power from the power line terminals with a power factor about equal to or higher than 80%.

12. The track lighting system of claim 7 wherein the high-frequency AC voltage is 100% amplitude-modulated.

13. The track lighting system of claim 12 wherein the high-frequency AC voltage is amplitude-modulated at a frequency equal to twice the frequency of the low-frequency AC voltage.

14. A track lighting system comprising:

a source providing a low-frequency AC voltage at a pair of power line terminals;

a power track having a pair of track conductors as well as a receptacle slot operable to receive and hold track lighting units with socket terminals operative to make electrical contact with the track conductors; and

voltage conditioning means connected between the power line terminals and the track conductors; the voltage conditioning means including a full-bridge rectifier and an inverter means; the full-bridge rectifier being connected directly with the power line terminals and being operative to supply rectified unfiltered low-frequency AC voltage to the inverter means; the voltage conditioning means being operative;

(i) to provide an amplitude modulated high-frequency AC voltage to the track conductors; the fundamental frequency of the high-frequency AC voltage being very much higher than that of the low-frequency AC voltage;

(ii) to power track lighting units connected with the track conductors; and

(iii) to draw power from the power line terminals with a power factor of at least 80%.

15. The track lighting system of claim 14 wherein the inverter means includes a half-bridge inverter.

16. The track lighting system of claim 14 wherein the high-frequency AC voltage is a squarewave voltage.

17. A track lighting system comprising:

a source providing a low-frequency AC voltage at a pair of power line terminals;

a power track having a pair of track conductors as well as a receptacle slot operable to receive and hold track lighting units with socket terminals operative to make electrical contact with the track conductors; and

voltage conditioning means connected between the power line terminals and the track conductors; the voltage conditioning means being operative to provide an amplitude modulated high-frequency squarewave voltage to the track conductors; the fundamental frequency of the high-frequency squarewave voltage being substantially higher than that of the low-frequency AC voltage.

* * * * *

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US005180952A

United States Patent [19]

Nilssen

[11] **Patent Number: 5,180,952**

[45] **Date of Patent: Jan. 19, 1993**

[54] **ELECTRONIC TRACK LIGHTING SYSTEM**

[76] Inventor: **Ole K. Nilssen**, Caesar Dr., Barrington, Ill. 60010

[21] Appl. No.: **831,086**

[22] Filed: **Feb. 7, 1992**

Related U.S. Application Data

[63] Continuation of Ser. No. 611,334, Nov. 13, 1990, abandoned, which is a continuation of Ser. No. 484,278, Feb. 26, 1990, abandoned, which is a continuation-in-part of Ser. No. 387,370, Jul. 31, 1989, abandoned, which is a continuation of Ser. No. 108,963, Oct. 16, 1987, abandoned, which is a continuation of Ser. No. 741,132, Jun. 4, 1985, abandoned, which is a continuation-in-part of Ser. No. 667,691, Nov. 2, 1984, abandoned, which is a continuation-in-part of Ser. No. 487,817, Apr. 22, 1983, Pat. No. 4,506,318.

[51] **Int. Cl.**^{5} **H05B 37/00**; H05B 39/00; H05B 41/26

[52] **U.S. Cl.** .... **315/210**; 315/209 R; 315/226; 315/DIG. 5

[58] **Field of Search** .... 315/201, 205, 209 R, 315/210, 226, DIG. 5, DIG. 7

[56] **References Cited**

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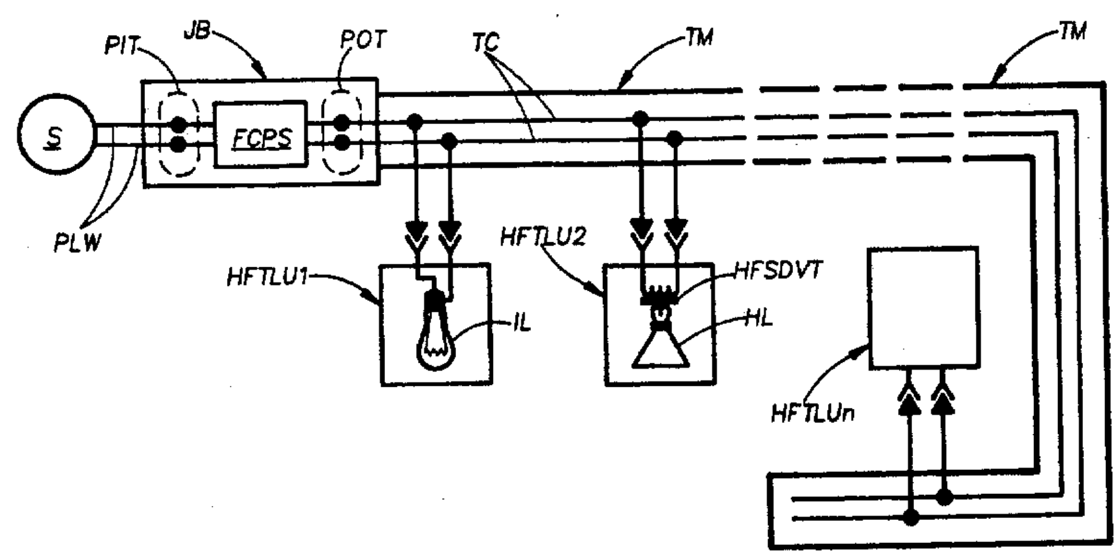
Primary Examiner—David Mis

[57] **ABSTRACT**

To permit the more cost-effective use of low voltage lamps (especially 12 Volt Halogen lamps) in track lighting systems, the power track is supplied from the power line by way of a frequency-converting power supply providing onto the track conductors a voltage of normal power line voltage magnitude (120 Volt RMS) but of an exceptionally high frequency (30 kHz). As a result, the individual step-down voltage transformer required to provide the proper low voltage for operating each of the low voltage lamps becomes very light, small and inexpensive. Yet, in contrast with situations where the whole track may be provided with low voltage from a single step-down voltage transformer, there will be no unusual limitations in respect to track length and/or the number of low voltage lamps that can be used with a given track. Moreover, there will be no problem with using regular high voltage incandescent lamps intermixed with low voltage lamps. For improved efficiency and reduced bulk, the frequency-conversion means placed at the head of the track is a direct-coupled rectifier-inverter combination.

13 Claims, 2 Drawing Sheets



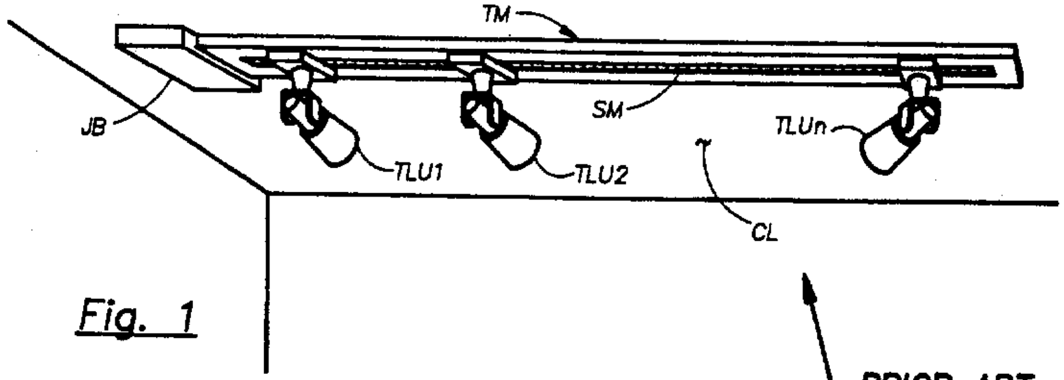


Fig. 1

PRIOR ART

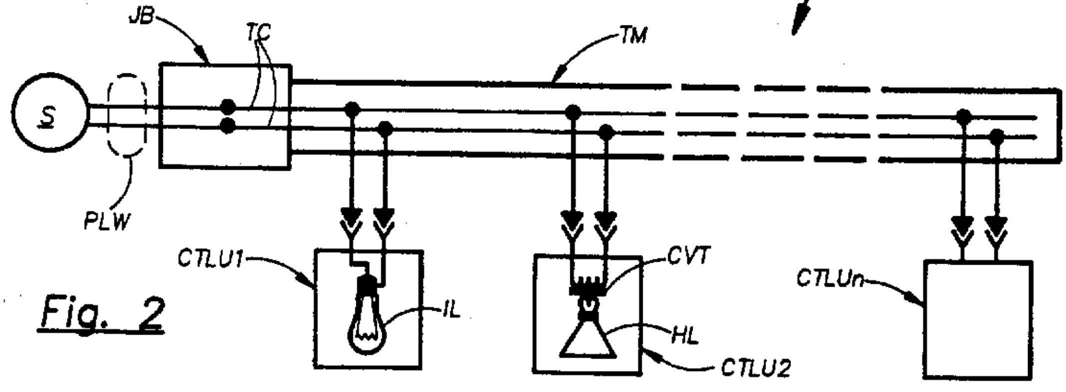


Fig. 2

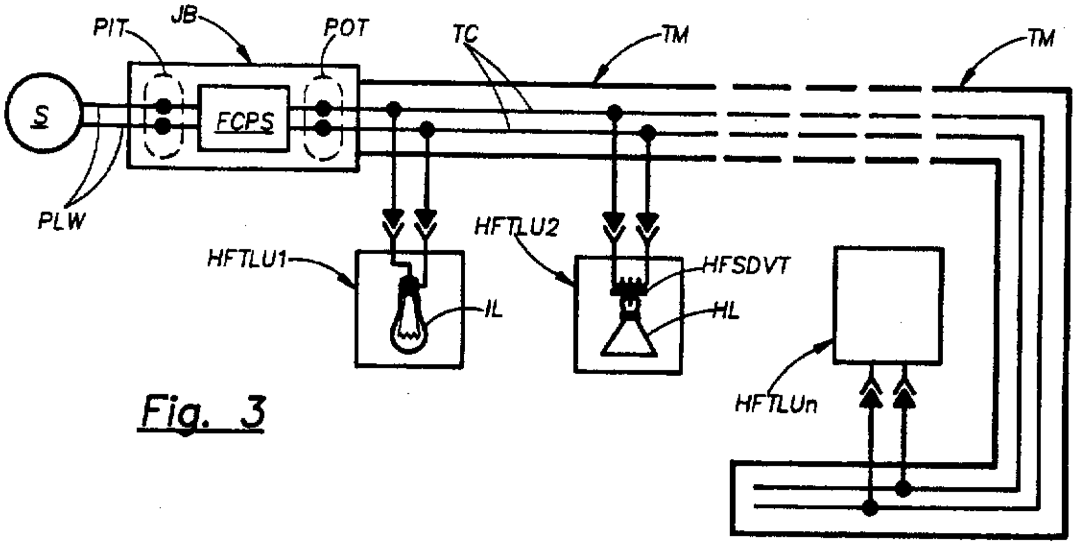


Fig. 3

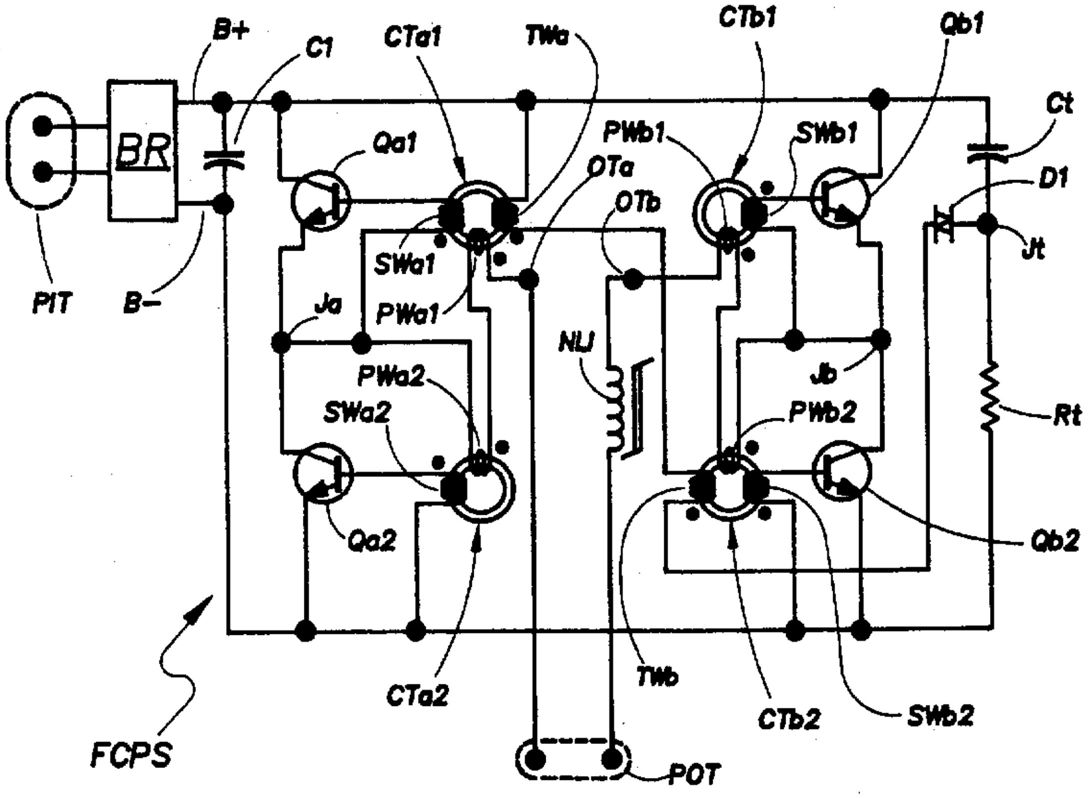

B+
C1
CTa1
TWa
CTb1
Qb1
Ct
BR
Qa1
PWb1
SWb1
OTa
OTb
D1
Jt
PIT
B−
SWa1
PWa1
Ja
NLI
Jb
PWa2
SWa2
PWb2
Rt
Qa2
Qb2
FCPS
CTa2
TWb
CTb2
SWb2
POT

Fig. 4

ELECTRONIC TRACK LIGHTING SYSTEM

RELATED APPLICATIONS

This application is a continuation of Ser. No. 07/611,334 filed Nov. 13, 1990, now abandoned; which is a continuation of Ser. No. 07/484,278 filed Feb. 26, 1990, now abandoned; which is a continuation-in-part of Ser. No. 07/387,370 filed Jul. 31, 1989, now abandoned; which is a continuation of Ser. No. 07/108,963 filed Oct. 16, 1987, now abandoned; which is a continuation of Ser. No. 06/741, 132 filed Jun. 4, 1985, now abandoned; which is a continuation-in-part of Ser. No. 06/667,691 filed Nov. 2, 1984, now abandoned; which is a continuation-in-part of Ser. No. 06/487,817 filed Apr. 22, 1983 now U.S. Pat. No. 4,506,318.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to track lighting systems, particularly of a kind that is being powered by way of a frequency-converting power supply and in such a way that the track voltage is of substantially normal magnitude (120 Volt RMS) but of a much higher than normal frequency (20–40 kHz).

2. Description of Prior Art

Track lighting systems are being manufactured by a number of different companies. One such company is Halo Lighting Division of McGraw-Edison Company, Elk Grove Village, Ill. 60007; whose track lighting systems and products are described in their Catalog No. A8100.

Conventional track lighting systems are designed to operate from a conventional utility power line and to have regular 120 Volt/60 Hz voltage on the track. The lighting units plugged into the track must be able to operate directly from this 120 Volt/60 Hz voltage.

Low voltage incandescent lamps particularly 12 Volt Halogen lamps, have proven to be particularly attractive for track lighting purposes, and are being used to a growing degree. However, these low-voltage/Halogen lamps are designed to operate at a voltage of 12 Volt or less, and therefore have to be powered by way of voltage step-down transformation means. Thus, at present, whenever low-voltage/Halogen lamps are being used in track lighting systems, each such low-voltage/Halogen lamp has to be powered by way of such a voltage step-down transformation means; which implies that each lighting unit has to contain such a voltage step-down transformation means—a practice that results in costly, large and heavy track lighting units.

The use of a single large step-down transformation means capable of providing power at a suitably low voltage to the complete track has been considered and tried. However, the resulting track current becomes prohibitively large for most applications.

(Since a conventional track is designed to handle a current of not more than 16 Amp, it would only be capable of powering three or four typical low-voltage/-Halogen lamps, which is far fewer than the number of lamps that would be required in most applications.)

SUMMARY OF THE INVENTION

Objects of the Invention

A first object of the present invention is that of a power-line-operated track lighting system that is particularly suitable for use with low-voltage incandescent lamps.

A second object is that of a track lighting system wherein the track is provided with a voltage of magnitude substantially equal to that of regular power line voltages but of a frequency substantially higher than those of regular power line voltages.

These as well as other objects, features and advantages of the present invention will become apparent from the following description and claims.

Brief Description

The present invention relates to means by which the track (or tracks) in a power-line-operated track lighting system is provided with a voltage of magnitude substantially equal to that of the voltage on the power line (120 Volt RMS), but of frequency much higher than that of the power line voltage.

In the preferred embodiment, this higher frequency is approximately 30 kHz; and this 30 kHz track voltage is obtained by way of a power-line-operated full-bridge inverter located at the head of the power track and feeding its output to the track conductors.

With such a high frequency on the track, and with the voltage being approximately of 120 Volt RMS magnitude, the voltage step-down transformation means required for operating low-voltage incandescent lamps (particularly 12 Volt Halogen lamps) are far smaller, lighter and lower in cost as compared with their 60 Hz counterparts.

At the same time, regular 120 Volt incandescent lamps may be used on the track, usually without any voltage transformation means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 diagrammatically illustrates a typical track lighting system.

FIG. 2 diagrammatically illustrates the electrical circuit arrangement of a typical present track lighting system.

FIG. 3 diagrammatically illustrates the electrical circuit arrangement of the preferred embodiment of subject invention.

FIG. 4 represents a schematic circuit diagram of the frequency-converting power supply used in the preferred embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Description of the Drawings

In FIG. 1, JB represents an electrical junction box in a ceiling CL. Fastened to and extending along the ceiling from this junction box is an electrical track means TM. This track means comprises a slot means SM by way of which a number of track lighting units TLU1, TLU2, - - - TLUn are removably fastened to and connected with the track.

In FIG. 2, a source S provides a 120 Volt/60 Hz power line voltage across a pair of power line wires PLW, which power line wires enter junction box JB. A pair of track conductors TC connect directly with these power line wires. These track conductors exit from the junction box and extend for the length of track means TM. Disconnectably connected with the track conductors are a number of conventional track lighting units CTLU1, CTLU2 - - - CTLUn.

Track lighting unit CTLU1 comprises an ordinary 120 Volt incandescent lamp IL, the electrical terminals of which are disconnectably connected directly across the track conductors.

Track lighting unit CTLU2 comprises a 12 Volt Halogen lamp HL, the electrical terminals of which are connected with the secondary winding of a conventional 60 Hz step-down voltage transformer CVT. The primary winding of this transformer is disconnectably connected directly across the track conductors.

In FIG. 3, power line wires PLW from source S enter junction box JB wherein they connect with power input terminals PIT of frequency-converting power supply FCPS. The output from frequency-converting power supply FCPS, which is an AC voltage of about 120 Volt RMS magnitude and 30 kHz frequency, is provided at power output terminals POT; which power output terminals are connected with track conductors TC. These track conductors exit from the junction box and extend for the length of track means TM. Disconnectably connected with the track conductors are a number of high-frequency track lighting units HFTLU1, HFTLU2 - - - HFTLUn.

High-frequency track lighting unit HFTLU1 comprises an ordinary 120 Volt incandescent lamp IL, the electrical terminals of which are disconnectably connected directly across the track conductors.

High-frequency track lighting unit HFTLU2 comprises a low voltage (12 Volt) Halogen lamp HL, the electrical terminals of which are connected across the secondary winding of a small high-frequency step-down voltage transformer HFSDVT. The primary winding of this transformer is disconnectably connected directly across the track conductors.

FIG. 4 constitutes an electric circuit diagram of frequency-converting power supply FCPS.

In FIG. 4, a bridge rectifier BR has a pair of power input terminals PIT adapted to connect with ordinary 120 Volt/60 Hz power line voltage.

The positive voltage output from rectifier BR is connected with a B+ bus; and the negative voltage output from rectifier BR is connected with a B− bus. A capacitor C1 is connected betweeen the B+ bus and the B− bus.

A transistor Qa1 is connected with its collector to the B+ bus and with its emitter to a junction Ja. Another transistor Qa2 is connected with its collector to junction Ja and with its emitter to the B− bus.

Similarly, a transistor Qb1 is connected with its collector to the B+ bus and with its emitter to a junction Jb; while yet another transistor Qb2 is connected with its collector to junction Jb and with its emitter to the B− bus.

The base of transistor Qa1 is connected with junction Ja by way of secondary winding SWa1 on current transformer CTa1; and the base of transistor Qa2 is connected with the B− bus by way of secondary winding SWa2 of current transformer CTa2.

Similarly, the base of transistor Qb1 is connected with junction Jb by way of secondary winding SWb1 on current transformer CTb1; and the base of transistor Qb2 is connected with the B− bus by way of secondary winding SWb2 of current transformer CTb2.

An output terminal OTa is connected with junction Ja by way of series-connected primary windings PWa1 and PWa2 of current transformers CTa1 and CTa2, respectively.

Another output terminal OTb is connected with junction Jb by way of series-connected primary windings PWb1 and PWb2 of current transformers CTb1 and CTb2, respectively.

Output terminals OTa and OTb are connected with power output terminals POT by way of a non-linear inductor NLI.

A capacitor Ct is connected between the B+ bus and a junction Jt; and a resistor Rt is connected between junction Jt and the B− bus. A Diac D1 is connected between junction Jt and the B+ bus by way of series-connected tertiary windings TWa and TWb of current transformers CTa1 and CTb2, respectively.

Details of Operation

The operation of an ordinary track lighting system, such as the one illustrated in FIG. 1, is well understood. In particular, it involves the mounting of a track onto and along a surface, such as a ceiling; which track comprises a slot that is capable of receiving, holding and powering a number of various types of track lighting units. Any one or all of these track lighting units can readily be removed from and/or moved along the track.

When a track lighting unit is inserted into the slot, it makes electrical contact with a pair of conductors therein; from which pair of conductors it gets its operating power.

For further information with respect to ordinary track lighting systems, as well as with respect to a track lighting system designed for powering the track conductors with a voltage of 12 Volt RMS magnitude, reference is made to Galindo. U.S. Pat. No. 4,414,617.

As illustrated by FIG. 2, in a conventional track lighting system, the track operating power is provided in the form of an ordinary 120 Volt/60 Hz voltage; which voltage is provided to the conductors in the track directly from a conventional electric utility power line.

As illustrated by FIG. 3, in a track lighting system according to the present invention, the track operating power is provided in the form of 120 Volt/30 kHz voltage; which voltage is provided to the track from the output of frequency-converting power supply FCPS.

Frequency-converting power supply, which operates in the manner described hereinbelow, is powered from the ordinary 120 Volt/60 Hz power line voltage provided by an ordinary electric utility power line.

With a 120 Volt/30 kHz voltage on the track, it becomes particularly simple and cost-effective to provide for various voltage transformations and/or current limitations, etc.—as required by the various lighting means useful in track lighting.

For instance, in respect to lighting unit HFTLU1, no transformation means at all is required for an ordinary 120 Volt incandescent lamp; which, of course, is not any different from the case with 120 Volt/60 Hz on the track.

On the other hand, in respect to lighting unit HFTLU2, a transformer means must be used to provide the requisite voltage step-down transformation required by the 12 Volt Halogen lamp used therein. However, with the frequency of the track voltage being so high, the size, weight and cost of this transformer are substantially smaller than those of the transformer required in lighting unit CTLU2 of the conventional track lighting system.

Frequency-converting power supply FCPS of FIG. 4 comprises a bridge rectifier (BR) operative to provide unfiltered full-wave-rectified 120 Volt/60 Hz power line voltage between the B+ bus and the B− bus. The purpose of capacitor C1 is that of providing a low-impedance path for 30 kHz inverter currents. However, it provides substantially no filtering for the full-wave-rectified power line voltage present between the B+ bus and the B− bus.

Thus, the voltage applied to the full-bridge inverter, which consists principally of transistors Qa1, Qa2, Qb1 and Qb2, is a series of sinusoidally-shaped unidirectional voltage pulses provided at the rate of 120 pulses per second. The RMS magnitude of this pulsed DC voltage is 120 Volt—just as is the RMS magnitude of the AC voltage applied to the full-bridge rectifier means BR.

In other words, the RMS magnitude of the DC voltage applied to the full-bridge inverter is 120 Volt; which—as long as the inverter oscillates—makes the RMS magnitude of the inverter output voltage also 120 Volt.

Otherwise, except for the function of non-linear inductor NLI, the operation of the full-bridge inverter of FIG. 4 is entirely analogous to that of the half-bridge inverter described Nilssen in U.S. Pat. No. 4,506,318.

The inverter self-oscillates by way of current feedback provided by the four positive feedback current transformers CTa1, CTa2, CTb1 and CTb2; which means that the inverter will not oscillate without having a load connected between its power output terminals POT. Thus, the inverter used in the frequency converter of FIG. 1 stops oscillating whenever special light bulb SLB is switched OFF or removed.

The function of non-linear inductor NLI relates to the fact that the load presented to power output terminals POT is substantially resistive and may vary from as little as a single 20 Watt lamp to as much as, say, ten 50 Watt lamps. The function of non-linear inductor NLI is that of providing an inductance in series with the resistive load; which inductance is of such nature as to represent: (i) a relatively high inductance value as long as the load current is relatively small (i.e., for relatively light loads); but (ii) due to saturation, a relatively low inductance value for relatively high loads. That way, regardless of the magnitude of the output current, the inductor provides for a brief delay in the reduction (or reversal) of load current in response to a reduction (or reversal) of the magnitude of the inverter's output voltage; which brief delay will be present at all different levels of load and will help prevent destructive and/or highly dissipative common-mode conduction of the switching transistors; which common-mode conduction results from transistor storage time effects. The net effect of the non-linear inductor on the effective or RMS magnitude of the output voltage will be negligible; which is to say: as long as the inverter indeed oscillates, the absolute instantaneous magnitude of the inverter's output voltage will at all times be substantially equal to the absolute instantaneous magnitude of the DC supply voltage existing between the B− bus and the B+ bus. And, of course, as an inherent result of full-wave rectification, the absolute instantaneous magnitude of this DC supply voltage is substantially equal to that of the power line voltage provided at power input terminals PIT.

Thus, as long as the inverter of frequency-converting power supply PCPS indeed oscillates, the voltage present across power output terminals POT is a 30 kHz squarewave voltage with an absolute instantaneous magnitude about equal to that of the power line voltage provided at power input terminals PIT.

In fact, as long as the inverter indeed oscillates, since the forward voltage drops of the rectifiers and transistors are each of negligible magnitude, and since the voltage drops across the primary windings of the four current transformers are each of negligible magnitude, and since the net effective voltage drop across non-linear inductor NLI is of negligible magnitude, then the absolute instantaneous magnitude of the output voltage present across power output terminals POT must inherently be substantially equal to that of the input voltage present across power input terminals PIT—as long as the magnitude of this input voltage is substantially larger than the sum of the various voltage drops.

As seen from another perspective, the function of the inverter is simply that of rapidly switching each one of the output terminals (f.ex. OTa) back and forth between the B− bus and the B+ bus. As a result, during any given half-cycle of the power line voltage, the inverter simply operates to rapidly (at a 30 kHz rate) switch each one of its output terminals (f.ex. OTa) between the two power line conductors (as connected with terminals PIT). Thus, with reference to FIG. 3, frequency-converting power supply FCPS simply acts to connect power line wires PLW with track conductors TC in a rapidly reversing manner—as if the two pairs of wires were connected by way of a rapidly reversing (or oscillating) four-pole reversing switch. This inherently means that one of the track conductors is always electrically connected with one of the power line wires; which, in turn, means that the electrical potential of one of the track conductors is always equal to the electrical potential of one or the other of the conductors of the power line wires.

ADDITIONAL COMMENTS

(a) Without having to resort to the use of a power transformer, subject invention provides for the flexibility of furnishing voltages to the track that are of significantly different magnitudes than 120 Volt RMS. For instance, by using a half-bridge inverter, it is readily possible—without the use of a voltage transformer—to furnish the track with a voltage of 60 Volt RMS magnitude even if the power line voltage is 120 Volt.

(b) Transformer HFSDVT of the track lighting arrangement of FIG. 3 is designed to be powered at its primary winding with a voltage of about 30 kHz frequency. The transformer would not function at all if it were to be powered at its primary winding with a voltage of ordinary power line frequency (i.e., 60 Hz).

(c) In the frequency-conversion circuit of FIG. 4, an important characteristic is that there always exists an electrically conductive path between either one of power output terminals POT and either one of power input terminals POT.

(d) As long as the frequency-converting power supply (FCPS) is in actual operation, the output voltage provided at power output terminals POT is a squarewave voltage of frequency equal to about 30 kHz and with absolute instantaneous magnitude about equal to that of the power line voltage provided at power input terminals POT; which is to say that, at any moment in time, the absolute magnitude of the voltage existing between track conductors TC is substantially equal to that of the power line voltage existing between power input terminals PIT.

(e) It is believed that the present invention and its several attendant advantages and features will be understood from the preceeding description. However, without departing from the spirit of the invention, changes may be made in its form and in the construction and interrelationships of its component parts, the form herein presented merely representing the preferred embodiment.

I claim:

1. An arrangement comprising:

a source providing a power line voltage between a first and a second power line terminal;

a power track having a first and a second track conductor; the power track being operative to receive and hold a number of track lighting units; each one track lighting unit having a pair of load terminals; which load terminals, when the one track lighting unit has been received and is indeed being held by the power track, make electrical connection with the track conductors; and

voltage conditioner means connected in circuit between the power line terminals and the track conductors; the voltage conditioner means being operative to convert the power line voltage provided between the power line terminals to a track voltage provided betweeen the track conductors; there being, through the voltage conditioner means, an electrical conduction path between the first track conductor and one of the power line terminals; the fundamental frequency of the track voltage being substantially higher than that of the power line voltage.

2. The arrangement of claim 1 wherein the absolute instantaneous magnitude of the track voltage is substantially equal to that of the power line voltage during a significant part of each half-cycle of the power line voltage.

3. The arrangement of claim 1 wherein the first track conductor is, via action occurring within the voltage conditioner means, alternatively and periodically switched between the first and the second power line terminal at the frequency of the track voltage.

4. The arrangement of claim 1 wherein the first track conductor is, via action taking place within the voltage conditioner means, periodically connected with the first power line voltage; such that, while such connection is taking place, the electrical potential of the first track terminal is substantially the same as that of the first power line terminal.

5. An arrangement comprising:

a source providing a power line voltage between a first and a second power line terminal;

a power track having a first and a second track conductor; the power track being operative to receive and releaseably hold a number of track lighting units; each one track lighting unit having a pair of load terminals; which load terminals, when said one track lighting unit has been received and is indeed being held by the power track, make electrical connection with the track conductors; and

voltage conditioner means connected in circuit between the power line terminals and the track conductors; the voltage conditioner means being characterized by functioning: (i) repeatedly and periodically to connect for a brief period of time the first track conductor with the first power line terminal, and (ii) in such manner as to provide between the track conductors a track voltage having a fundamental frequency substantially higher than that of the power line voltage.

6. The arrangement of claim 5 wherein the brief period of time has a duration that is approximately equal to half that of the fundamental period of the track voltage.

7. An arrangement comprising:

a source providing a power line voltage between a first and a second power line terminal;

a power track having a first and a second track conductor; the power track being operative to receive and releaseably hold a number of track lighting units; each one track lighting unit having a pair of load terminals; which load terminals, when said one track lighting unit has been received and is indeed being held by the power track, make electrical connection with the track conductors; and

voltage conditioner means connected in circuit between the power line terminals and the track conductors; the voltage conditioner means being characterized by functioning: (i) periodically and alternatively to cause electrical connection between the first track conductor and the first and second power line terminals, and (ii) to provide between the track conductors a track voltage having a fundamental frequency substantially higher than that of the power line voltage.

8. An arrangement comprising:

source means providing a power line voltage between a pair of power line terminals; and

power track and lighting means characterized by including:

(a) a pair of main input terminals connected with the power line terminals;

(b) a pair of track conductors;

(c) a slot means;

(d) a track lighting unit having an incandescent lamp with a pair of lamp terminals, the track lighting unit also having a pair of power input terminals and a pair of power output terminals; the power output terminals being connected with the lamp terminals; the track lighting unit being inserted into the slot means, thereby to cause the power input terminals to connect with the track conductors; and

(e) voltage conditioner means connected in circuit between the main input terminals and the power output terminals;

the power track and lighting means being further characterized by functioning such that:

(f) there exists an electrical conduction path between the track conductors and the power line terminals; and

(g) an output voltage exists across the lamp terminals; the output voltage being of frequency substantially higher than that of the power line voltage and having an RMS magnitude that varies periodically in synchronism with, as well as in proportion with, the instantaneous absolute magnitude of the power line voltage.

9. An arrangement comprising:

source means operative to provide a power line voltage at a pair of power line terminals;

voltage conditioner means; and

power track means having track conductors and track receptacle means; the track conductors being: (i) connected with the power line terminals by way of the voltage conditioner means, and (ii) having a track voltage of frequency substantially higher than that of the power line voltage; there being, by way of the voltage conditioner means, an electrical conduction path between the track conductors and the power line conductors.

10. The arrangement of claim 9 wherein the track voltage has an RMS magnitude that is proportional to the instantaneous absolute magnitude of the power line voltage.

11. An arrangement comprising:

source means operative to provide a power line voltage at a pair of power line terminals;

power track means having track conductors and track receptacle means operable to receive and hold plural track lighting units; and

voltage conditioner means connected between the power line terminals and the track conductors; the voltage conditioner means being operative: (i) to provide to the track conductors a track voltage of frequency substantially higher than that of the power line voltage; and (ii) to cause an electrical conduction path to exist between the track conductors and the power line conductors.

12. An arrangement characterized by comprising:

a power track means having track conductors and a receptacle slot; the track conductors being connected in circuit with a pair of power line conductors of an ordinary electric utility power line; an AC power line voltage being present at the power line conductors; and

plural lighting units; each lighting unit: (i) having a pair of input terminals, (ii) being operable to be inserted into the receptacle slot and to connect with the track conductors, (iii) having an incandescent lamp with a pair of lamp terminals, and (iv) when indeed being inserted into the receptacle slot, causing a high-frequency voltage to be applied to the lamp terminals; the frequency of the high-frequency voltage being substantially higher than that of the AC power line voltage; the RMS magnitude of the high-frequency voltage being modulated in direct proportion with the instantaneous absolute magnitude of the AC power line voltage.

13. An arrangement comprising:

a power line providing an AC power line voltage at a pair of power line terminals; and

power track means having a pair of track conductors connected in circuit with the power line terminals; the power track means having a receptacle slot operative to receive and disconnectably hold a number of track lighting units; a track voltage existing between the track conductors; the voltage being of frequency substantially higher than that of the power line voltage; the instantaneous absolute magnitude of the track voltage being substantially equal to that of the power line voltage.

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