(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 119 584**
B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **18.01.89**

(51) Int. Cl.[4]: **H 05 B 41/29**

(21) Application number: **84102738.6**

(22) Date of filing: **13.03.84**

(54) Lighting circuit for electric discharge lamp.

(30) Priority: **14.03.83 JP 41806/83**
15.04.83 JP 66349/83
29.06.83 JP 117852/83
16.08.83 JP 149302/83
10.01.84 JP 2269/84
10.01.84 JP 2270/84
10.01.84 JP 2271/84
10.01.84 JP 2272/84

(43) Date of publication of application:
26.09.84 Bulletin 84/39

(45) Publication of the grant of the patent:
18.01.89 Bulletin 89/03

(84) Designated Contracting States:
DE FR GB NL

(56) References cited:
GB-A-2 073 510
US-A-4 087 722

(73) Proprietor: **MITSUBISHI DENKI KABUSHIKI KAISHA**
2-3, Marunouchi 2-chome Chiyoda-ku
Tokyo 100 (JP)

(72) Inventor: **Yamazaki, Hiroyoshi**
613-8, Iwase
Kamakura-shi Kanagawa-ken (JP)
Inventor: **Minagawa, Yoshiji**
7-4-408, Tsurugaoka
Chigasaki-shi Kanagawa-ken (JP)
Inventor: **Tsuchihashi, Michihiro**
461-2-253, Terabun
Kamakura-shi Kanagawa-ken (JP)
Inventor: **Anzai, Yoshinori**
7-1395-36, Sakurayama
Zushi-shi Kanagawa-ken (JP)
Inventor: **Kajiwara, Toshiro**
494-22, Nakada-cho Totsuka-ku
Yokohama-shi Kanagawa-ken (JP)

(74) Representative: **Liesegang, Roland, Dr.-Ing.**
FORRESTER & BOEHMERT Widenmayerstrasse
4 Postfach 22 01 37
D-8000 München 22 (DE)

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European patent convention).

Courier Press, Leamington Spa, England.

EP 0 119 584 B1

Description

This invention relates to a lighting circuit for an electric discharge lamp having the features of the preamble of claim 1.

First of all, explanations will be given as to the conventional technique for operating the low pressure electric discharge lamp by application of a voltage having a pause-time period.

According to US—A—4,078,722, which relates to a lighting circuit according to the preamble of claim 1, the switching device is arranged to periodically stop energisation of the discharge lamp by the control device in that the switching device is switched ON and OFF for bringing the lamp to flash.

For the purpose of dimming a gas discharge lamp GB—A—2,073,520 discloses a switching device having a control circuit. The switching device supplies a commercial voltage to the discharge lamp. The discharge lamp is fed in intervals around the maximum instantaneous value of the supplied commercial voltage.

Japanese unexamined utility model publication No. 4779/1973 discloses a lighting circuit of a construction, in which use is made of a turn-off thyristor provided in parallel with a fluorescent lamp to thereby convert a lamp voltage V_L in a sinusoidal waveform into a plurality of pulse voltage as shown in Figure 1(a) of the accompanying drawing. This lamp voltage V_L, however, is of commercial frequency, the purpose of which is to reduce a size of a choking coil as a current limiting impedance, hence the prior art invention differs from the present invention.

In the above-described conventional technique, the pulse voltage in the half cycle of the commercial frequency is in one and the same direction. However, JP—A—36786/1976 discloses an improved technique, wherein the pulse voltage is made in an alternate direction. This prior right invention also aims at size-reduction of the choking coil, the frequency band for use of which is different from that of the present invention, hence no improvement can be attained in the operating efficiency of the low pressure electric discharge tube to be mentioned later.

Further JP—A—115078/1976 discloses a lighting circuit for a fluorescent lamp having a capacitive current limiting impedance composed of a serial connection of a capacitor 1 and a choking coil 2 as shown in Figure 1(b), wherein a switching device 4 is provided in parallel with a lamp 3 to effect short-circuiting of the switching device once every half cycle at the trailing part (those hatch-lined portions in Figure 1(c)) of the lamp current I_L in a sinusoidal waveform of a commercial frequency. This disclosed art is, however, to facilitate restrike of the electric discharge lamp by increasing a charging voltage V_C of the capacitor 1 at the time of the restriking.

US—A—3,789,266 discloses improvement in efficiency of the abovementioned electric discharge lamp, wherein a high frequency interrupted current having a conduction period T_1 and a breaking period (hereinafter called "pause-time period") T_0, and the current direction of which reserves at every changing of the conduction period and the pause-time period. A device for flowing electric current such as mentioned above is limited to a circuit shown in Figure 2(b). This circuit is constructed with a bridge circuit, in which transistors 5, 6, 7 and 8 are arranged on four sides and an electric discharge lamp 9 is connected across the diagonal line; another transistor 10 provided in series with the input side of the bridge circuit; and a control device 11 which performs controls of opening and closing of the transistors 5, 6, 7, 8, and 10 to thereby cause electric current to flow as shown in Figure 2(a).

In such a device, however, the voltage to be applied to the transistors 5, 6, 7 and 8 is a rectangular waveform, at a high voltage portion of which the pause-time period T_0 is formed by the transistor 10 with the consequent disadvantages such that the capacity of the device should essentially be made larger, and that the radio noise is also high. As the results of various studies and experiments made on the operating of the low pressure mercury-vapor electric discharge lamp such as fluorescent lamp with a high frequency voltage having the pause-time period as disclosed in JP—A—196497/1982 and Japanese patent application No. 110369/1981, the present inventors have discovered that the lamp efficiency can be further improved from the values as shown in the above-discussed US—A—3789266.

It is therefore the main object of the present invention to provide a lighting circuit having much higher utility than those lighting circuits disclosed in the above-mentioned Japanese documents.

It is another object of the present invention to provide a lighting circuit for an electric discharge lamp which has reduced the above-mentioned various disadvantages inherent in the conventional device, wherein use is made of a high frequency inverter to energize a low pressure electric discharge lamp, the inverter having a characteristic such that its output voltage take a substantially sinusoidal waveform. In such a high frequency inverter, a pause-time period T_0 is formed at least at a rising part of its sinusoidal output voltage where an instantaneous value is small, and the electric power is supplied to the above-mentioned low pressure electric discharge lamp at a portion where the instantaneous value of the above-mentioned output voltage is large, thereby increasing efficiency of the abovementioned low pressure electric discharge lamp, and reducing the radio noise with the lighting circuit of a relatively small capacity.

These and other objects are accomplished according to the present invention by the features of claim 1.

The specific constructions, functions, and operating principle as of the lighting circuit for an electric discharge lamp according to the present invention will become more apparent under-

standable from the following detailed description of preferred embodiments thereof, when read in conjunction with the accompanying drawing.

In the accompanying drawings:

Figures 1(a), 1(b) and 1(c) are explanatory diagrams of a conventional device;

Figures 2(a) and 2(b) are explanatory diagrams of another conventional device and its circuit construction;

Figure 3 is a circuit diagram showing the first embodiment of the lighting circuit according to the present invention;

Figure 4 is a diagram of the main part of the circuit shown in Figure 3;

Figures 5(a), 5(b), 5(c) and 5(d), and Figures 6(a), 6(b), 6(c), 6(d) and 6(e) are respectively explanatory diagrams of the lighting circuit shown in Figure 3;

Figure 7 is a circuit diagram showing a second embodiment of the present invention;

Figure 8 is a diagram showing the main part of the circuit shown in Figure 7;

Figure 9 is a diagram showing a third embodiment of the circuit according to the present invention;

Figure 10 is a diagram showing a main part of a fourth embodiment of the circuit according to the present invention;

Figure 11 illustrates waveform diagrams for explaining a fifth embodiment of the circuit according to the present invention;

Figure 12 is a diagram showing a main part of a sixth embodiment of the circuit according to the present invention;

Figure 13 illustrates waveform diagrams for explaining the circuit shown in Figure 12;

Figure 14 is an explanatory diagram of a seventh embodiment of the circuit according to the present invention;

Figure 15 is a diagram showing an eighth embodiment of the circuit according to the present invention;

Figure 16 is an explanatory diagram for the circuit shown in Figure 15;

Figure 17 is a diagram showing a ninth embodiment of the circuit according to the present invention;

Figure 18 is a diagram showing a tenth embodiment of the circuit according to the present invention;

Figure 19 is a diagram showing an eleventh embodiment of the circuit according to the present invention;

Figure 20 is a diagram of the main part of the circuit shown in Figure 19;

Figure 21 is an explanatory diagram for the device shown in Figures 19 and 20;

Figures 22(a), 22(b), 22(c), and 22(d) are waveform diagrams for explaining a twelfth embodiment of the circuit according to the present invention;

Figure 23 is a diagram showing the twelfth embodiment of the circuit according to the present invention;

Figure 24 is a diagram showing the main part of the circuit shown in Figure 23;

Figures 25(a), 25(b), 25(c), and 25(d) are waveform diagrams for explaining a thirteenth embodiment of the circuit according to the present invention;

Figures 26(a), 26(b), and 26(c) are diagrams for explaining operations of a fourteenth embodiment of the circuit according to the present invention in relation to the first embodiment thereof;

Figures 27 and 28 are the circuit diagrams for the fourteenth embodiment of the circuit according to the present invention;

Figures 29 and 30 are respectively the diagrams showing a fifteenth and a sixteenth embodiment of the circuit according to the present invention;

Figures 31(a), 31(b) and 31(c) are diagrams for explaining the operations of the sixteenth embodiment of the circuit according to the present invention;

Figures 32(a), 32(b), 32(c), 32(d), and 32(e) are the diagrams for explaining the operations of a seventeenth embodiment of the circuit according to the present invention in relation to the twelfth embodiment thereof;

Figure 33 is a diagram of the seventeenth embodiment of the lighting circuit for an electric discharge lamp according to the present invention;

Figure 34 is a diagram showing an eighteenth embodiment of the lighting circuit according to the present invention;

Figure 35 is a diagram showing a control device for the lighting circuit for the electric discharge lamp according to a nineteenth embodiment of the present invention;

Figures 36(a), 36(b), and 36(c) are the diagrams for explaining the operations of the lighting circuit for the electric discharge device according to the nineteenth embodiment of the present invnetion;

Figure 37 is a diagram of a twentieth embodiment of the lighting circuit according to the present invention;

Figures 38(a), 38(b), 38(c), 38(d), 38(e), and 38(f) are operating waveform diagrams of the lighting circuit according to the twentieth embodiment of the present invention;

Figure 39 is a diagram showing a twenty-first embodiment of the lighting circuit according to the present invention;

Figure 40 is a diagram for a control device relative to the twenty-first embodiment of the lighting circuit according to the present invention; and

Figure 41 is a diagram for explaining the operation of the circuit according to the twenty-first embodiment of the present invention.

In the following, the present invention will be described in detail with reference to preferred embodiments thereof shown in the accompanying drawing.

Referring first to Figure 3 showing a circuit

diagram of the lighting circuit for an electric discharge lamp according to the first embodiment of the present invention, a reference numeral 12 designates a commercial alternating current power source, a numeral 13 refers to a rectifying device for the full-wave rectification of the power source 12, a numeral 14 refers to a smoothing capacitor, and a reference numeral 15 denotes a high frequency inverter to energize a fluorescent lamp 16 as a low pressure electric discharge lamp. In this embodiment, there is used a self-excited, constant current type push-pull transistor inverter.

The inverter 15 is constructed as mentioned in the following: a high frequency choking coil 17 provided at the input terminal of the inverter 15; an output transformer 18; the primary windings 18a, 18b, at the junction of which the high frequency choking coil 17 is connected a feedback winding 18c; a secondary winding 18s; pre-heating windings 18f, 18f to preheat the preheating type electrodes 16f, 16f of lamp 16; a power source winding 18d of a control device 19 to be described later; a resonating capcaitor 20 connected in parallel with the primary windings 18a, 18b; a pair of transistors 21a, 21b as the active components connected between the primary windings 18a, 18b and the negative terminal of the capacitor 14; a pair of base resistors 22a, 22b; and a choking coil 23 which functions as a current limiting impedance to the electric current flowing through the lamp 16. A reference letter *A* designates a switching device provided in parallel with the lamp 16 at the output terminals of the inverter 15, and includes with a full-wave rectification circuit 24, the alternating current terminals of which are connected in parallel with the lamp 16, and a transistor 25 disposed at the direct current terminals of this rectification circuit 24.

Figure 4 is a circuit diagram showing one embodiment of the control device 19 for the transistor 25. In the drawing, a reference numeral 18d designates the power source winding provided in the transformer 18, a numeral 26 refers to a diode bridge which performs the full-wave rectification of a high frequency of a low voltage induced in the winding 18d, a reference numeral 27 represents a smoothing capacitor connected with the output terminal of the diode bridge 26 through a back-flow preventing diode 28, and a reference numeral 29 denotes a transistor connected in parallel with the capacitor 27 through a resistor 30, which transistor 29 is also disposed between the base and the emitter of the transistor 25. A reference numeral 31 designates a constant voltage diode connected with the base of the transistor 29 through a resistor 32.

In the lighting circuit of such construction as mentioned above, when a voltage is applied to it from the power source 12, a smoothed direct current formed by the rectification device rectifier 13 and the capacitor 14 is introduced as an input into the inverter 15, whereby the transistors 21a, 21b are opened and closed alternately by the actions of the primary windings 18a, 18b, the resonating capacitor 20, the feedback winding 18c, and so forth, and the inverter 15 starts its self-oscillation. In this case, the collector current of the transistors 21a, 21b is rendered to be in a substantially rectangular waveform by the action of the high frequency choking coil 17, whereby the voltage in the primary windings 18a, 18b assumes a substantially sinusoidal waveform. As the result of this, there is generated in the power source winding 18d a high frequency voltage of, for example, 20 kHz, in a substantially sinusoidal waveform, as shown in Figure 5(a). This high frequency voltage is subjected to the full-wave rectification by the diode bridge 26, from which a voltage as shown in Figure 5(b) is applied to the constant voltage diode 31. The capacitor 27 is charged, and a smoothed direct current is applied to the serial circuit of the resistor 30 and the transistor 29. Assume now that the constant voltage diode 31 is interrupted in the hatch-lined portion and becomes conductive in the white portion, as shown in Figure 5(b). A voltage across the collector and the emitter of the transistor 29 takes a shape as shown in Figure 5(c), while the transistor 25 becomes conductive at the trailing part T_{01} and the rising part T_{02} of the output voltage in the secondary windings 18s in a substantially sinusoidal waveform (in general, a high harmonic component is superposed in it to some extent) as shown in Figure 5(d) to thereby form the pause-time period T_0, and it is interrupted during a period T_1 in the vicinity of the maximum instantaneous value of the output voltage, whereby a voltage as shown by a hatch-lined portion in Figure 5(d) is applied to the lamp 16.

On the other hand, the electrodes 16f are preheated by a voltage in the sinusoidal waveform which has been induced in the preheating windings 18f, and, as soon as the electrodes 16f are heated to a predetermined temperature level, the lamp 16 is lit. In this case, the voltage to be applied to the lamp 16 (i.e., the voltage in the hatch-lined portion in Figure 5(d)) lowers for a portion of a voltage drop in the choking coil 23, although it hardly changes during the time periods of T_1, T_{01}, T_{02}, and T_0. The reason for this is that a starting voltage for the lamp 16 at its high frequency operating is in general higher than in the case of the commercial frequency operating, and the voltage for operating the lamp is low, on account of which the inverter 15 has a constant current characteristic at the output side, and the output current of the inverter 15 assumes a substantially continuous sinusoidal waveform at the time of both conduction and interruption of the transistor 25.

The output current is in substantially the same waveform as that shown in Figure 5(d), the blank portion indicating a short-circuit current flowing in the switching device *A*, and the hatch-lined portion indicating a lamp current flowing in the lamp 16.

In the conventional circuit shown in Figure 2(b), and those circuit shown in the afore-described Japanese unexamined patent publication No.

196497/1982 and Japanese patent application No. 110369/1981, the output voltage as shown in Figure 2(a) is only applied to the lamp 9, etc. through the current limiting impedance, so that no lamp current as shown in Figure 2(a) can be obtained unless the current limiting impedance is a resistor (even in this case, it is difficult to put this circuit construction into practice so far as a complicated control circuit is added to it, since the power loss is great). More specifically, in the case of the inductive impedance, the lamp current takes a triangular waveform with gentle rising, while, in the case of the capacitive impedance, the lamp current takes a triangular waveform with gentle trailing, both cases not being able to afford sufficient lamp efficiency, and the efficiency being particularly low in the former case. This is due to the fact that the improvement in the lamp efficiency by the provision of the pause-time period T_0 owes very much to the effect such that the electron density at a high temperature level becomes higher than at the time of direct current operating and commercial frequency operating by causing a current with a steep rising part to flow in the lamp which has been cooled during the pause-time period T_0.

Unlike the conventional device as mentioned above, the circuit construction of this embodiment of the present invention, wherein the switching device *A* is provided in parallel with the lamp 16, even if the constant current characteristic at the output side of the inverter 15, for example, is not so perfect as mentioned in the foregoing, there can be obtained fair waveforms with steep rising part as shown by the hatch-lined portions in Figure 5(d) for both voltage and current of the lamp 16 by the counter-electromotive force of the current limiting impedance 23 due to the short-circuit current, irrespective of whether the current limiting impedance 23 is resistance, inductance, or capacitance, whereby the operating efficiency of the lamp 16 improves remarkably.

Further, the output voltage from the bridge type inverter shown in Figure 2(b) is in a rectangular waveform V_A as shown in the right half of Figure 5(d), in contrast to which the output voltage from the inverter 15 is in a sinusoidal waveform as designated by V_S in Figure 5(d). In comparison with the rectangular waveform of the former, since the sinusoidal waveform of the latter has its pause-time period T_0 formed at a relatively small portion of the instantaneous voltage value, its output capacity can be smaller than the former.

The transistors 10 and 25 both perform their respective switching operations at a substantially same voltage and with a substantially same current, hence the switching loss may be substantially equal between both transistors. However, in contrast to that the transistors 5, 6, 7 and 8 perform their switching operations at a high voltage and with a current in the rectangular waveform, the collector current of the transistors 21a, 21b is in a rectangular half waveform as shown in Figure 6(a), but their voltage between the collector and the emitter is in a sinusoidal half waveform as shown in Figure 6(b), so that their switching loss is theoretically non-existent. Accordingly, the overall efficiency of the lighting circuit as a whole remarkably improves along with improvement in the operating efficiency of the lamp 16.

Further, in the bridge type inverter, the output voltage, the output current, and the collector current and the collector-emitter voltage of the transistors 5, 6, 7 and 8 are all in the rectangular waveform. In contrast to this, in the inverter 15 of the present invention, only the collector current of the transistors 21a, 21b is in the rectangular waveform, while the output voltage, the output current, and the collector-emitter voltage of the transistors 21a, 21b are all in the sinusoidal waveform with the consequence that the lighting circuit of the present invention has a lower radio noise than that in the conventional device.

The reason for the collector current of the transistors 21a, 21b taking the rectangular waveform as mentinoed above is as follows. It is now assumed that the output current from the inverter 15 is in the sinusoidal waveform as shown in Figure 6(c), in which the hatch-lined portion denotes the current flowing in the lamp 16, and the blank portion indicates the short-circuit current produced by the switching device A. If the high frequency choking coil 17 is not present, the output powers produced during the periods of T_{01} and T_{02} for the abovementioned short-circuit current are almost reactive powers, except for the preheating power for the electrode 16f in the inverter 15, with the consequence that the collector current in any one of the transistors 21a, 21b is small during the periods T_{01} and T_{02} as shown in Figure 6(d) and is large during the period T_1. The passage of a constant base current relative to such remarkably changing collector current not only increases the switching loss in the transistor 21a, 21b, when they are conductive, but also renders the operations of the inverter 15 instable. However, by the provision of the high frequency choking coil 17 having an appropriate inductance, the collector current is smoothed and takes a rectangular waveform as shown in Figure 6(e). Therefore, by stably operating the inverter 15 by means of a simple base drive circuit composed of the feed-back winding 18c and the base resistors 22a, 22b, the operating efficiency of the inverter 15 can also be improved. The abovementioned smoothing operation may not be perfect as depicted in Figure 6(e). Incidentally, the choking coil 17 has an effect of eliminating the high harmonic component to occur in the collector current. While such function may take place in a separately excited inverter, it is particularly effective in the self-excited inverter.

When a leakage type transformer is used as the output transformer 18, the power source winding 18d had better be provided to the side of the primary windings 18a, 18b.

Figure 7 is a circuit diagram showing the second embodiment of the lighting circuit accord-

ing to the present invention in which a reference numeral 33 designates a smoothing direct current power source same as that shown in Figure 3, and a numeral 15 refers to a self-excited, constant current type push-pull transistor inverter also same as that shown in Figure 3 with exception of using a capacitor 23 as the current limiting impedance. A reference letter *A* designates a switching device provided in series with the lamp at the output terminal of the inverter 15. This switching device *A* is constructed with the full-wave rectification circuit 24 with its a.c. terminals being serially connected with the lamp 16, and the transistor 25 provided at the d.c. terminal of this full-wave rectification circuit 24. A numeral 19 refers to the control device for the switching device, the details of which are shown in Figure 8. The control device 19 is constructed mostly same as that shown in Figure 4, with the exception that a signal reversing circuit comprising a serial connection of the resistor 34 and the transistor 35 is provided at the rear stage of the serial circuit composed of the transistor 29 and the resistor 30. By the way, in Figure 7, the electrode 16f and the preheating winding 18f are omitted from illustration.

In the glow starter circuit of the above-described construction, when the power source 33 is closed, the transistor 29 generates the signal as shown in Figure 5(c) by the same operations as has been explained with reference to Figure 4. Accordingly, the transistor 35 generates a signal, in which the periods of its conduction and interruption are reversed from those in Figure 5(c) with the result that the transistor 25 is interrupted during the period T_0 and conducted during the period T_1, whereby a voltage as shown in the hatch-lined portion of Figure 5(d) is applied to the lamp 16, as is the case with the first embodiment of the lighting circuit shown in Figure 3. Since, after starting of the lamp, the current limiting impedance is the capacitor 23, both voltage and current having steep rising part can be obtained for starting the lamp 16, whereby its operating efficiency increases.

In this second embodiment, too, the pause-time period T_0 is formed with the periods T_{01} and T_{02}, during which the instantaneous value of the output voltage in the sinusoidal waveform is small, the operating efficiency of the lamp 16 is seen to be improved with the current limiting impedance of a capacity smaller than that shown in Figure 2.

Also, since the switching conditions of the transistor 21a, 21b are the same as that of Figure 3, the switching loss of the transistor is substantially nil.

In view of the fact that the output current from the inverter 15 is as shown by the hatch-lined portion in Figure 5(d), the radio noise increases more than that shown in Figure 3, but it is less than that shown in Figure 2.

Incidentally, the load applied to the inverter 15 during the pause-time period T_0 is only the preheating load of the electrode 16f, hence the effectiveness of the high frequency choking coil 17 as has been explained with reference to Figure 6 is equally applicable to this second embodiment.

In this embodiment, the variations in the load applied to the inverter during the pause-time period T_0 and the period T_1 for supplying power to the lamp 16 are greater than the load variations in the first embodiment as shown in Figure 3, more stable operations can readily be obtained with the inverter 15 of the separately excited type.

By the way, the capacitor 23 may be provided between the rectification circuit 24 and the lamp 16 to obtain the same resulting effect.

Figure 9 is a circuit diagram showing the third embodiment of the lighting circuit according to the present invention, in which the same reference numerals as those in the previous figures of drawing designate the identical or corresponding parts. The characteristic feature of this third embodiment resides in that the switching device *A* is connected to the output terminal of the inverter 15 through the electrodes 16f, 16f in parallel with the lamp 16. Incidentally, the control device 19 is the same as that shown in Figure 4, using the power source winding 18d as the power source.

The thus constructed lighting circuit operates in the substantially same manner as that shown in Figure 3, with the exception that current flows through the electrodes 16f, 16f during the pause-time period T_0 at the time of starting and lighting of the electric discharge lamp. Such device can also be operated in the same manner as that shown in Figure 3 without provision of the preheating winding 18f.

In each of the above-described three embodiments of the lighting circuit for an electric discharge lamp, the inverter 15 is constructed with the constant current type push-pull transistor inverter, but it may be replaced by a serial type transistor inverter as used in the fourth embodiment shown in Figure 10. This serial type transistor inverter 15 comprises a pair of transistors 36a, 36b and another pair of resonating capacitors 37a, 37b, these pairs of transistors and capacitors constructing the four sides of a bridge circuit, and a resonanting choking coil 38 and an output transformer 18, both being connected in series and disposed at the diagonal line in the bridge circuit. To the secondary winding 18s of the transformer 18, there are connected the switching device *A*, the control device 19, and the lamp 16 in any one of the arrangements shown in Figures 3, 7, and 9.

In the device of such construction, when the transistors 36a, 36b are alternately opened and closed in the base drive circuit 39 such as, for example, an integrated circuit (IC) for a switching regulator, there flows in the primary winding 18e a substantially sinusoidal vibrating current with its direction being reversed alternately, whereby a substantially sinusoidal output voltage is obtained in the secondary winding 18s. Consequently, the operating efficiency of the lamp 16

can be increased with the inverter 15 of a small capacity as is the case with the above-described embodiments. The radio noise is also low, since at least the output voltage and the collector current are in the sinusoidal waveform.

It should be noted that the abovementioned effect can be obtained with any type of the lighting circuit of a construction, in which the power supply to the lamp 16 is interrupted at least at the rising part of the voltage in the sinusoidal waveform for its half cycle, and the power supply to the lamp 16 is done in the vicinity of the maximum instantaneous value in the abovementioned half cycle.

Further, while the collector-emitter voltage in the transistors 36a, 36b is in the rectangular half waveform, its collector current is in the sinusoidal half waveform.

In this case, too, the switching loss is theoretically nil. Furthermore, when at least any one of the voltage and the current in the active elements of the inverter 19 is in the sinusoidal waveform, the effect as mentioned above can be obtained with other inverter 15.

Although, in the above-described embodiments, the input into the inverter 15 is the smoothed direct current, those devices having the smoothing capacitor 14 incorporated therein is low in the power factor. Therefore, in the ordinary high frequency operation, there is a practice of using a pulsating voltage obtained by full-wave rectification of the a.c. voltage from the power source 12 as the input voltage for the inverter. Figure 11 shows the output voltage and the output current of the inverter in that case, in which the voltage is an alternating current voltage containing beats therein. However, if the frequency of the inverter is assumed to be, for example, 25 kHz, there exists in the half wave of 50 kHz a high frequency voltage of 250 cycles, whereby the output voltage is in the substantially sinusoidal waveform, when taken in a short period of time.

While such lighting circuit reduces its lamp efficiency to some degree on account of the lamp current becoming quiescent during a time period T_0 starting from the zero volt condition in the power source 12. However, when the fifth embodiment of the present invention is applied to such lighting circuit, the operating efficiency of the lamp 16 can be increased to a considerable degree, hence its power factor can be made high.

With a view to eliminating the current pause-time period T_0 as mentioned above, it has usually been a practice in the high frequency operation to provide an auxiliary power source, with which the output voltage from the inverter can be obtained even at the zero voltage level in the power source 12. Figure 12 illustrates the circuit construction for one example of such auxiliary power source. The auxiliary power source 44 as illustrated is constructed with a step-down transformer 40, a full-wave rectification circuit 41 to perform the full-wave rectification on the output voltage, a capacitor 42 connected to the d.c. terminal of the rectification circuit, and a diode 43. By the way, both terminals of the capacitor 42 are connected with the input terminal of the high frequency inverter 15 through the diode 43.

In the thus constructed auxiliary power source, when the instantaneous value of the pulsating voltage which has been subjected to the full-wave rectification by the rectification device 13 becomes lower than the charged voltage of the capacitor 42, the input voltage of the inverter 15 is supplied from the capacitor 42, and the output voltage and the output current from the inverter 15 are as shown in Figure 13, wherein the current pause-time period T_0 is absent, with the consequence that the lamp efficiency improves. When the present invention is applied to such construction, there can be obtained various effects as mentioned above, and the lighting circuit with high power factor and an extremely high general efficiency. This is the sixth embodiment of the lighting circuit according to the present invention.

In the above-described embodiments of the present invention, the switching device *A* is constructed with a combination of the rectification circuit 24 and the transistor 25. It should however be noted that the same effect can also be obtained by use of other switching elements such as a turn-off thyristor, etc.

Although the control device 19 changes its characteristics by the kind of the switching element used for the switching device *A*, there may be contemplated various kinds of control device such as, for example, the one using a combination of a comparator IC and the drive circuit of the switching element, the one using clock pulses, the one using an integrated circuit (IC) for the switching regulator, or various others.

For example, when the control device using the clock pulses is employed as the control device 19, it become possible to carry out the power supply to the lamp 16 for twice or more of the time periods T_{11} und T_{12} in the half cycle of the high frequency output voltage. Even with such control device, the operating efficiency of the lamp 16 can be improved, as shown in Figure 14 which is the seventh embodiment of the lighting circuit of the present invention.

In the preceding description, no particular mention has been made as to the frequency of the inverter 15. However, by the provision of the pause-time period T_0 as disclosed in detail in Japanese patent application No. 110369/1981, the improvement in the resulting lamp efficiency is recognized from a frequency of 1 kHz or its vicinity, and, even at the frequency of 80 kHz, considerable improvement could still be obtained. However, from the standpoint of preventing disagreeable audible noises, the frequency of about 17 kHz and above is preferable. Further, when a bipolar type transistor is used for the transistor 25, the frequency of 100 kHz or below is preferable for reducing the switching loss.

In the above-described embodiments, the lamp

16 used is single, although the same effect can be resulted, even when two or more serially connected lamps 16 are used.

Further, in the above-described embodiments, the low pressure electric discharge lamp used is the fluorescent lamp 16. However, the improvenent in the lamp efficiency due to provision of the pause-time period T_0 could be recognized in other types of the rare gas electric discharge lamp such as a neon lamp 16, a krypton lamp 16, etc., hence the lighting circuit of the present invention can be equally applied to these low pressure electric discharge lamps 16.

Figure 15 is a circuit diagram showing the eighth embodiment of the lighting circuit according to the present invention. In the drawing, those reference numerals same as those in Figure 3 designate the identical or corresponding parts. In this embodiment, unlike the device shown in Figure 3, the output transformer for the inverter 15 is constructed with a leakage type transformer 18, and an auxiliary winding 18R wound in subtractive polarity at its secondary side is connected with the secondary windings 18S to form a low voltage cable way E. To this low voltage cable way E, there is connected the switching device *A* same as that shown in Figure 3. On the other hand, the secondary winding 18S forms a high voltage cable way F, to which the fluorescent lamp 16 is connected. By the way, the control device 19 is this eighth embodiment of the present invention is exactly same as that of Figure 4, with the exception that the power source winding 18d thereof is wound at the primary side. It should be noted also that the preheating circuit for the electrodes 16f, 16f in the lamp 16 is omitted from the illustration.

In the lighting circuit of the construction as described above, when the power source 11 is closed, the inverter 15 commences its oscillation in the same manner as that in Figure 3, and the control device 19 introduces into the transistor 25 an input signal same as that shown in Figure 5(c). As the result of this, the transistor 25 becomes conductive during the period T_0. However, since the transformer 18 is of the leakage type, the voltage applied to the lamp 16 also assumes substantially zero volt. On the other hand, in the time period T_1, the transistor 25 is interrupted and a voltage in the vicinity of the maximum instantaneous value of the winding 18S is applied to the lamp 16, whereby it is lit. In this case, if the number of winding turns of the windings 18S and 18R is set n_S and n_R, respectively, and a no-load peak voltage of the winding 18S is represented by V_{SO}, there is applied to the transistor 25 a voltage

$$V_{SO} \cdot \frac{n_S - n_R}{n_S} \cdot$$

After the operation, the lamp 16 is kept lighting with a voltage as shown in the hatch-lined portion in Figure 5(d), and the same effect as that of Figure 3 can be obtained.

In this case, it should be noted that a diode of low voltage withstand and high speed response can be used for the transistor 25 and the rectification circuit 24, hence it becomes possible not only to construct the device with high reliability and at a reduced manufacturing cost, but also to further increase the general efficiency of the device.

However, in the above-described construction of the circuit, since the windings 18S and 18R are wound in the subtractive polarity, the electric current I_S at the time of conduction of the transistor 25 becomes greater than the lamp current I_L as shown in Figure 16 with the consequence that there take place problems such that not only a switching element of a large current capacity need be used as the switching device *A*, but also the power loss thereof becomes great. Figure 17 is a circuit diagram showing the nineth embodiment of the lighting circuit according to the present invention, in which the abovementioned point is improved. In Figure 17, the control device 19, etc. are omitted from the illustration. In this embodiment, the choking coil 33 as the current limiting impedance is added in series with the switching device *A* in the low voltage cable way shown in Figure 15.

In the circuit of such construction, the current I_S at the time of conduction of the switching device *A* can be reduced to thereby improve the abovementioned problem.

However, when the impedance value of the choking coil 33 is made too large, the voltage to be applied to the lamp 16 at the time of conduction of the switching device *A* becomes large. When this voltage value becomes higher than a discharge maintaining voltage at the time of restriking of the lamp 16, the lamp commences its discharge before the switching device *A* is interrupted, and the rising in the voltage and the current for the lamp 16 are no longer steep, thereby hindering improvement in the lamp efficiency.

Further, in the lighting circuit, wherein the inverter 15 is of the self-excited type, as in the above-described embodiments, if a difference between the current I_S and the current I_L is too large, the oscillation of the inverter tends to become instable. The choking coil 33 has the effect of stabilizing the oscillation by reducing the current I_S.

Figure 18 is a circuit diagram showing the tenth embodiment of the lighting circuit according to the present invention. This embodiment performs the same operations as that shown in Figure 15 and attains the same effect, even if both low voltage cable way E and high voltage cable way F are individually provided at the secondary side of the transformer 18. In this case, the polarity of the windings 18S and 18R has no bearing on the operation of the transformer 18.

Figure 19 is a diagram showing the eleventh embodiment of the lighting circuit according to the present invention, in which a tap T is provided at the intermediate point of the secondary winding 18S to form the low voltage cable way E. A

reference numeral 46 designates a current transformer provided in the high voltage cable way F, the signal of which is input into the control device 19.

Figure 20 is a circuit diagram showing details of the control device 19 for the eleventh embodiment, in which a starting auxiliary means C to be explained hereinbelow is added to the circuit shown in Figure 4. In the drawing, a reference numeral 47 designates a transistor connected in parallel with the capacitor 27 through the resistor 48, a numeral 49 refers to a transistor arranged in parallel with the transistor 29, a numeral 50 refers to a diode bridge which performs the full-wave rectification of the output signal from a current transformer 46, a reference numeral 51 denotes a smoothing capacitor, a numeral 52 indicates a base resistor of the transistor 47, and a reference numeral 53 designates a diode interposed between the collector of the transistor 49 and the base of the transistor 25. A capacitor 54 and a resistor 55 are connected in series between the positive polarity of the capacitor 27 and the base of the transistor 25 to thereby form a time constant circuit. By the way, in this case, the power source winding 18d of the control device 19 and the preheating winding 18f of the electrode 16f (not shown) is provided at the primary side of the transformer 18.

In the device of such construction, when the power source 11 is closed, the base current flows in the transistor 25 through the abovementioned time constant circuit. On the other hand, since no signal has yet been generated in the current transformer 46, the transistor 47 is in an interrupted condition, hence there is no possibility of current flowing into the transistor 49 from the time constant circuit due to presence of the diode 53, even if the transistor is in a conductive state. Further, while the transistor 29 performs the same operations as that shown in Figure 4, its signal does not flow into the transistor.49 to be input into the transistor 25.

That is to say, during the initial period of from t_0 to t_1 at the start of the lamp 16 shown in Figure 21, the electrode 16f is preheated by the winding 18f. However, since the switching device *A* continues its conductive state, substantially no voltage is applied to the lamp 16, hence it is not operated.

After lapse of a predetermined time instant t_1, when the capacitor 54 is sufficiently charged and the base current of the transistor 25 is rendered substantially zero, the transistor 25 is brought to an interrupted state. However, since no signal is generated in the current transformer 46, the transistor 49 maintains its conductive state and the transistor 25 also maintains its interrupted state during a period of from t_1 to t_2, on account of which a no-load voltage of the secondary winding 18S is applied, as it is, to the lamp 16. The electrode 16f is sufficiently preheated during a period of from t_0 to t_1, and still continues its preheating even during a period of from t_1 to t_2. Therefore, a time interval is required more or less for the lamp 16 to shift from its glow discharge to its arc discharge, although this time period of from t_1 to t_2 is a relatively short time interval.

When the lamp 16 starts at a time instant t_2, a signal is generated in the current transformer 46, and the transistor 47 becomes conductive. On account of this, the transistor 49 is interrupted and the signal generated in the transistor 29 is input into the transistor 25. As the result of this, the lamp 16 is operated with a voltage having its pause-time period of T_0 and its voltage applying period of T_1.

As mentioned in the foregoing, by making the conduction period of the switching device *A* at the initial stage of the lamp starting longer than the conduction period at the time of operating of the lamp to sufficiently preheat the electrode 16f without starting the lamp 16, and then by making the interruption period of the switching device *A* longer than the interruption period at the time of the operating of the lamp 16, it becomes possible not only to start the lamp 16 without shortening the service life of the lamp, but also to set the secondary no-load voltage of the transformer 18 to be low, whereby the capacity of the lighting circuit can be made much smaller and the loss in the device can be further reduced.

Incidentally, when the transistor 47 becomes conductive with a signal to be generated in the current transformer 46 when the lamp 16 is in its flow discharge condition during a period of from t_1 to t_2, there is a possibility such that the lamp 16 remain in its glow discharge condition, or, if not remaining in this glow discharge condition, a time is taken for the lamp to shift from the glow discharge to the arc discharge, thereby shortening the service life of the lamp. In order to avoid such awkward situation to take place, it is preferable that an element such as, for example, a constant voltage diode, etc. which does not operate with a signal at the time of the glow discharge, but operate with a signal at the time of the arc discharge be provided in the base circuit of the transistor 47.

In the above-described embodiment of the present invention, the switching device *A* is constructed with a combination of the rectification circuit 24 and the transistor 25, although the same resulting effect can be obtained with those switching devices using other switching elements such as a field-effect transistor 25, and so on. Further, the control device 19 varies its function by the switching element used, and there are contemplated various kinds of such switching elements other than those used in the above-described embodiments.

Furthermore, in the above-described embodiment, the inverter 15 is a self-excited, constant current type push-pull transistor inverter. Besides this, there may also be used a serial inverter 15, for example, provided that the leakage type transformer 18 can be used as the output transformer, in which a substantially sinusoidal output voltage can be obtained.

Moreover, in the above-described embodiments, a smoothed d.c. voltage is used for the

power source 11. However, there may also be used a pulsating d.c. voltage obtained by the full-wave rectification of an a.c. voltage and a pulsating d.c. voltage obtained by supplying a voltage from the auxiliary power source in the vicinity of the zero volt.

In the following, the twelfth embodiment of the lighting circuit according to the present invention will be explained. This embodiment is concerned with further improvement in the afore-described first embodiment. By the way, the following fact has become evident as the result of detailed studies and researches on the operation of the device according to the first embodiment of the present invention.

Figure 22(a) indicates an output voltage V_{DB} of the diode bridge 26 of the control device 19 and a Zener voltage V_Z of the constant voltage diode 31 of the same. Figure 22(b) shows an interrupted period T_{1a} of the transistor 25 in the switching device. Figure 22(c) shows an output current from the inverter 15. Due to presence of the choking coil 23, the output current from the inverter has its phase delayed from the output voltage from the inverter 15, i.e., the output voltage V_{DB} from the diode bridge 26. This output voltage V_{DB} is clipped by the constant voltage diode 31 to form the period T_1. However, since the output voltage from the inverter 15, i.e., the output voltage from the diode bridge 26 is at a high frequency level, if the switching speed of the transistor 29, the transistor 25, and so forth is not so high, the interrupted period T_{1a} of the transistor 25 is delayed by t_d from the conduction period of the constant voltage diode 31. However, since the output current from the inverter 15 has also its phase delayed by θ_1 from the power source winding 18d, there flows in the lamp 16 the output current from the inverter 15 in the vicinity of its maximum instantaneous value as shown by the hatch-lined portion in Figure 22(c). In such a device, however, when a phase difference between the output current from the inverter 15 and the voltage of the power source winding 18d is very large, or when a high speed component is used for the transistors 25, 29, and so on in the control device 19 and the switching device *A* with a delay time being different from a predetermined value, there takes place such an apprehension that no current can be supplied to the lamp 16 with a desired phase. It has therefore been discovered that, in such case, there flows in the lamp 16 a current portion of a low instantaneous value in the output current, on account of which a capacity of the device becomes inevitably large for supplying a predetermined power to the lamp 16, and the operating efficiency of the device decreases due to flow of current in the vicinity of the maximum instantaneous value of the output current through the transistor 25.

With the abovementioned situation in mind, there has been devised the twelfth embodiment as shown in Figure 23, which serves to supply appropriate electric current to the lamp, even when the phase difference between the output current and the output voltage from the inverter is great, by detection of the output current from the inverter and by on-off controls of the switching device by this signal.

Figure 23 is the circuit diagram showing the twelfth embodiment of the present invention, wherein the same reference numerals as those in Figure 3 designate the identical or equivalent parts. Further, Figure 24 illustrates one embodiment of the control device 19 for use in the device according to the twelfth embodiment of the present invention.

In Figure 23, a reference numeral 33 designates a current transformer which detects the output current from the inverter 15 and inputs the current into the control device 19. In Figure 24, a numeral 33 refers to the same current transformer as mentioned above, a reference numeral 34 designates an output resistor for the current transformer 33, 35 a full-wave rectifier to rectify the output from the current transformer 33, 31 a constant voltage diode, and 36 a d.c. power source for driving the device, which can be constructed by, for example, rectifying and smoothing an output from the auxiliary winding provided in the transformer 18 of the inverter 15. This circuit construction is substantially same as that shown in Figure 4 with the only differences in that the input signal for the constant voltage diode 31 is derived from the full-wave rectification of the output from the current transformer 31, and that a signal reversing circuit consisting of a transistor 37 and a resistor 38 is added. Moreover, the graphical representation in Figure 22(d) indicates the output voltage from the current transformer 33, the output having a substantially same phase as, and analogous waveform to, those of the output current from the inverter 15, as a matter of course.

In the device of a construction as described above, the current transformer 33 does not produce an output voltage before the lamp 16 starts its electric discharge, and the transistor 25 maintains its interrupted conditions, on account of which the output voltage from the inverter 15 is applied to the lamp 16 as it is to facilitate commencement of its discharge. In the next place, when the lamp 16 starts its electric discharge, the current transformer 33 generates an output voltage. At this instant, the transistor 29 becomes conductive during the period T_{1a} including the maximum instantaneous value of the output current from the inverter 15 by means of the constant voltage diode 31 as shown in Figure 22(d), to thereby interrupt the transistor 25. As the consequence of this, the discharge current flows through the lamp 16 during this period T_{1a} as shown by the hatch-lined portion in Figure 22(c).

In this manner, when a current in the vicinity of the maximum instantaneous value of the output current from the inverter 15 is made to flow in the lamp 16, the capacity of the device can be made smaller than in the case wherein such current does not flow, and the operating efficiency of the device increases.

In the following, the thirteenth embodiment of the lighting circuit according to the present invention will be explained. In the twelfth embodiment as shown in Figure 23, the explanations have been given as to a case, wherein ripples are less in the input d.c. voltage for the inverter 15. In this embodiment, however, explanations will be made as to applications to those cases where a pulsating d.c. voltage containing more ripples in the input d.c. voltage is used, i.e., a pulse current obtained by simply rectifying the commercial a.c. power source as shown in Figure 25(a) is used; or where an auxiliary d.c. voltage having a low peak is superposed on the commercial a.c. power source as shown in Figure 25(c). In such instances, the current flowing in the lamp 16 takes its waveform as shown in Figures 15(b) and 25(d) when no switching device *A* is provided. Here, it is assumed that, in the control device 19 same as that shown in Figure 22, a level for detecting the output voltage from the current transformer 33 by means of the constant voltage diode 31 is set at a predetermined value A_L as shown in Figures 25(b) and 25(d). Then, at a portion where the peak value is higher than the predetermined value A_L, the control device performs the same operation as has been explained with reference to Figure 22, but, at a portion where the peak value is lower than the predetermined value A_L, the switching device *A* maintains its interrupted condition. By constructing the control device as such, i.e., by providing the pause-time period for only a period where the maximum instantaneous value of the lamp current is greater than the predetermined value A., and by flowing a current having no pause-time period for a period where the instantaneous value of the lamp current is low, it is possible to further improve the operating efficiency of the lamp 16.

In the foregoing, the explanations have been given as to an example of using the current transformer 33 for the control device 19. However, the other expedients such as, for example, one which detects the current by use of resistors, etc. may be used. Further, the constant voltage diode 31 is used for detection of the instantaneous value of the output current, which can also be replaced by a comparator IC, or the like for obtaining the same effect. Furthermore, in this embodiment, the switching device *A* is constructed with combination of the rectifying circuit 24 and the transistor 25, which can also be replaced by a field-effect transistor or other switching elements for obtaining the same effect.

The inverter 15 may be such one as, for example, a serial inverter, etc. provided that a substantially sinusoidal output voltage can be obtained at the output terminal thereof. Also, the current limiting impedance 23 to set the lamp current at a predetermined value may not be inductance of the inductive reactance, but a capacitor of capacitive reactance. Further, in the foregoing, explanations have been given as to a case, wherein the choking coil is used at the output terminal of the inverter 15, although the transformer 18 of the inverter 15 may be constructed as the leakage transformer.

Various arrangements of the switching device *A* are possible other than that in the embodiment. For instance, an additional winding in the opposite polarity as that of the secondary winding 18S of the transformer 18 is provided, through which the switching device *A* is connected; or when the transformer 18 is the leakage type transformer, an intermediate tap is provided in the secondary winding and the switching device A is connected with a low voltage cable way to be formed in this intermediate tap; or it may be feasible that an impedance is connected in series with the switching device *A* to reduce the current flowing through the switching device *A*. Furthermore, the switching device *A* is connected in parallel with the lamp 16 through the electrodes 16f, 16f thereof, and the preheating current is caused to flow at the time of conduction of the switching device *A*. Moreover, it may be feasible that, at the start of the lamp 16, the switching device *A* be maintained without operating the same for a certain period of time for stabilizing it even after commencement of the electric discharge.

In the following, the fourteenth embodiment of the present invention will be described. This embodiment is a further improvement in the first embodiment.

Incidentally, in the device, wherein the inverter 15 varies its output voltage in substantial correspondence to variations in the input d.c. voltage thereof as the device of the first embodiment shown in Figure 3, the voltage in the control winding 18d also varies in accordance with the input d.c. voltage of the inverter. Accordingly, when the input d.c. voltage of the inverter 15 is of a voltage waveform having large ripplies, i.e., if a difference between the maximum value (E_{max}) and the minimum value (E_{min}) of the input d.c. voltage as in the example shown in Figure 26(a), the voltage variations in the control winding 18d is remarkable ($E_{min}/E_{max}<0.8$ or so), hence the output signal from the control device 19 to be generated with the voltage of this control winding 18d as the input signal for its also varies. On account of this, the pause-time period T_0 varies greatly to possibly cause inconveniences in carrying out stable control of the device as well as in improving efficiency of the circuit. With this in mind, therefore, the circuit in this fourteenth embodiment is so constructed that the stable control of the circuit can be effected with a voltage obtained by use of this type of inverter as the input signal for the control device, which does not vary so remarkably even when the ripples in the input d.c. voltage become fairly large.

Figure 27 illustrates the fourteenth embodiment of the lighting circuit according to the present invention, and Figure 28 shows a concrete embodiment of the control device therefor. It is to be noted that explanations will be made with reference to Figure 27 only for those parts which are different from those in the circuit of the Figure 3 embodiment.

A reference numeral 14 designates an auxiliary d.c. power source having a peak value lower than the peak value of the output voltage from the smoothing capacitor or the rectifying circuit 13. The output transformer 18 contains therein the current limiting impedance constructed with a leakage type transformer. To the switching device *A*, is connected an impedance 26 (in this embodiment, a choking coil) in series. This choking coil 26 is set at such an inductance value that no current may flow in the lamp 16 during a period when the switching device is in a conductive state.

In Figure 28, a reference numeral 18d represents a control winding; a numeral 28 refers to a resistor; 29 a constant voltage diode; 30 a transistor; 31 a resistor; and 32 a control d.c. power source, which can also be obtained by rectifying and smoothing an output from the control winding provided at the primary side of the output transformer 18.

In the device as constructed in the abovementioned manner, it is assumed that the input d.c. voltage for the inverter 15 is as shown in Figure 26(a). As is the case with the circuit of the Figure 3 embodiment, the inverter 15 carries out the self-oscillation to generate a high frequency voltage, thereby operating the lamp 16. Here, the output transformer 18 is the leakage type transformer, wherein the control winding 18d wound around the magnetic circuit at the secondary side of this transformer generates a voltage analogous to the voltage from the secondary winding 18s, i.e., a voltage analogous to the voltage appearing across the terminals of the lamp 16. In the illustrated circuit, the impedance 26 functions to generate in the control winding 18d a voltage above the minimum required level when the switching device *A* becomes conductive.

Now, with variations in the input d.c. voltage for the inverter 15, the output current from the inverter varies as shown in Figure 26(b). However, since the lamp voltage does not change so remarkably even if the lamp current values change, it does not change so remarkably as shown in Figure 26(c). Accordingly, the voltage in the control winding 18d does not change so remarkably, whereby the constant voltage diode 29 of the control device 19 causes electric current to flow for a substantially same period of time at every half cycle of the high frequency voltage to render the transistor 30 conductive. On account of this, even if the input d.c. voltage for the inverter 15 varies, the transistor 25 of the switching device *A* is brought to its conductive state for a substantially constant period T_0 as shown by the hatch-line in Figure 5(b). In this way, it is possible to provide an appropriate pause-time period.

Figure 29 illustrates the fifteenth embodiment of the lighting circuit according to the present invention, in which the control device 19 is further provided with resistors 35, 37, a constant voltage diode 33, a capacitor 34, and a transistor 36. Before start of the electric discharge in the lamp 16, the transistor 36 is rendered and maintained in a conductive state in utilization of the phenomenon that the voltage in the secondary winding 18s and the control winding 18d is higher during this period than at the time of operating of the lamp, thereby keeping the switching device in an interrupted state and facilitating start of the lamp.

In the above explanations, a choking coil is used as the impedance 26, although it goes without saying that a capacitor may also be used for the purpose. From the standpoint of obtaining a quick rising of the current to be supplied to the lamp 16, this latter component is preferred. In the case of using the choking coil, it may be connected to the output side of the full-wave rectifying circuit.

In the foregoing explanations, the impedance 26 is connected in series with the switching device *A* to thereby generate a required voltage in the control winding 18d even when the switching device is in a conductive state. When no impedance 26 is connected, the winding provided in the magnetic circuit at the secondary side does not produce a voltage in the leakage transformer during conduction of the switching device. The following is an embodiment of the circuit which is applicable to such case.

Figure 30 shows the sixteenth embodiment of the lighting circuit according to the present invention, wherein the construction is the same as that shown in Figure 25 with the exception of the control device 19 (also no impedance 26 is provided). The point of difference in this embodiment from that shown in Figure 26 is that the capacitor 38 is connected with the output terminal of the control device 19.

In the following, operations of the circuit in this embodiment will be explained. Figures 31(a), 31(b) and 31(c) are diagrams for explaining the operations of the circuit according to the sixteenth embodiment of the present invention, wherein the solid line in Figure 31(a) indicates an output current from the secondary winding 18s of the inverter, and a hatch-lined portion denotes the current flowing in the lamp 16; the solid line in Figure 31(b) indicates an output voltage from the full-wave rectifying circuit 27 of the control device; and Figure 31(c) shows a voltage to be applied across the base and the emitter of the transistor 25.

During the operating of the lamp, the output voltage from the control winding 18d lowers, and when it goes down below V_Z in Figure 31(b), the transistor 30 is brought to an interrupted state, while the transistor 25 is rendered conductive to stop the power supply to the lamp. However, after a predetermined time to be set by a time constant of the resistor 31 and the capacitor 38 (a period of T_0 in Figure 31(b)), the transistor 25 returns to its interrupted state and the current begins to flow again in the lamp. An output voltage from the full-wave rectifying circuit 27 at this time is represented by V_x. Then, a signal as shown in Figure 31(c) is applied to the transistor 25. In the embodiment device, the relationship between V_x and V_z can be arbitrarily established as: $V_x > V_z$, $V_x \simeq V_z$,

and $V_x<V_z$, by appropriate selection of the pause-time period T_0. The method for generating this pause-time period T_0 may be any one, other than that in the above-described embodiment, such as use of an appropriate timer, use of a monostable multi-vibrator, and others.

It is further possible that the lighting circuit according to the sixteenth embodiment shown in Figure 30 be used in combination with a device as shown in Figure 29 for not generating the pause-time period at the time of starting the lamp.

It is also useful that the switching device is connected in parallel with the lamp through its filament, the conduction period T_0 of the switching device is extended (or the interruption period T_1 is omitted) at the time of starting the lamp so as to sufficiently preheat the filament, thereafter the conduction period T_0 is shortened (or T_0 may be omitted) to facilitate starting of the lamp discharge, and, after operating of the lamp, the conduction period T_0 and the interruption period T_1 be set at their initial values.

In the foregoing explanations, use has been made of a voltage from the control winding wound at the secondary side of the leakage type output transformer as an input signal into the control device. However, when a voltage which is substantially analogous to the voltage across the lamp terminals is used, the intended purpose can be achieved. Therefore, it is feasible to connect a signal generating transformer in parallel with the lamp so that a voltage from the winding provided on this transformer may be used as the input signal for the control device, in which case the device with the impedance 23 being connected therewith may also be used. Next, when a phase difference exists between the input signal and the voltage across the lamp terminals, it may suffice that this phase difference be compensated and the switching device be subjected to the on-off controls. This can also be realized, in the case of using the leakage transformer according to this embodiment, as by appropriate adjustment of the winding position of the control winding.

For the inverter 15, the self-excited, push-pull inverter is suited. Besides this, any type of inverter, which is capable of stopping the power supply to the lamp at least at the rising part of a substantially sinusoidal output current at every half cycle thereof, and of performing the power supply to the lamp in the vicinity of the maximum instantaneous value thereof. The output transformer may not necessarily be the leakage type transformer.

For the auxiliary d.c. power source 14, there may be used a low d.c. voltage to be obtained by use of a transformer, etc., or such voltage generated from voltage dividing by the serial connection of a plurality of capacitors, and by other expedients. In short, the d.c. voltage may contain therein the ripples, if only it is able to maintain the lamp discharge.

In each of the above-described embodiments, the switching device *A* used is constructed with the rectifying circuit 24 and the transistor 25. However, this switching device may also be constructed with other switching elements, etc. having a required characteristic. Furthermore, other connection device may be adopted, if the power supply stoppage period to the lamp can be provided.

In the following, the fifteenth embodiment of the present invention will be described. This embodiment is a further improvement of the afore-described twelfth embodiment.

In the afore-described twelfth embodiment, the lamp 16 is operated by the circuit construction shown in Figure 23; however, when the electric discharge becomes difficult due to the service life of the lamp reaching its end, or no regular discharge can be done in any longer due to progress in consumption of one if the electrodes to bring about the asymmetrical discharge, etc., wherein the discharge is effected with only one of the polarities, there inevitably occurs the phenomenon to be mentioned in the following. That is to say, in case the switching device A is conductive during a period including the phase θ_0 in Figure 5(c) and this conductive state is interrupted at the phase θ_1, there will be no problem at all so far as the current flows through the lamp 16. However, when no current flows in the lamp 16 for some reason, the choking coil 23 as the current limiting impedance is abruptly interrupted from its current flow to generate a high voltage due to the counter-electromotive force, which is applied to the switching device *A*. On acocunt of this, there is apprehension such that a large stress is applied to the components parts constituting the switching device to lower reliability of the device. This is also true with the case wherein the output transformer 18 is constructed as the leakage transformer, and no choking coil 23 is used.

In this embodiment, therefore, attempt is made as to improving reliability of the switching device by providing a surge absorbing circuit having an appropriate response time without impairment being cause to the lamp operation.

First of all, prior to the explanations of the fifteenth embodiment of the lighting circuit according to the present invention, the basic principle of the present invention will be explained.

The rising part of the current and voltage in the lamp 16 (a time instant t_1 or its vicinity shown in Figures 32(d) and 32(e)), when the lamp is operated with the lighting circuit according to the twelfth embodiment shown in Figure 23, can be shown in an enlarged waveform in these figures of drawing. When the neighboring area of the time instant t_1 is observed in detail, it is seen that a current increase exists in the lamp current, as shown by a broken line in Figure 32(d). This current increase varies in accordance with magnitude of impedance in the choking coil 23. Also, the lamp voltage at its rising part t_1 is at a lower value V_1 than a value V_2 which can be anticipated from the locus of the original inverter output voltage, as shown in Figure 32(e), and it becomes

substantially coincident with the locus of the original output voltage after the time instant t_2. A time required for this time period between t_1 and t_2 is approximately 2 μs (more accurately, longer than 1.5 μs but not reaching 3 μs) with a fluorescent lamp of 40W capacity, for example. This phenomenon may be inferred due to the current flowing in the vicintiy of the tube wall of the lamp at the restriking thereof for every half cycle, though the detailed reasons therefor is yet to be clarified.

The lighting circuit in this fifteenth embodiment of the present invention purports to effectively utilize the voltage dropping phenomenon to occur at the rising part of the lamp voltage as mentioned above, thereby reducing the voltage to be applied to the switching device. In the following, the embodiment will be explained in reference to the drawing.

Referring to Figure 33, a reference numeral 37 designates a surge absorbing circuit, a numeral 38 refers to a diode, 39 and 40 refer to resistors, and 41 a capacitor. The remaining construction of the device according to this embodiment are the same as that shown in Figure 23, hence the corresponding parts are designated by the same reference numerals and the explanations for them are dispensed with.

In the lighting circuit for the electric discharge lamp of the abovementioned construction, the surge absorbing circuit 37, in its normal operation, performs its charging operation to some extent at the rising part t_1 of the voltage at every half cycle of the lamp operation, although the main charging operation thereby is set to be in a constant which terminates within 3 μs. Accordingly, irrespective of presence of the surge absorbing circuit 37, the lamp 16 indicates its lamp voltage at a substantial equal level to that when no surge absorbing circuit is provided.

In the following, explanations will be made as to a case when the lamp 16 is not in a position to perform its normal discharging operation. If it is now assumed that the lamp 16 is discharging from only one of the electrodes 16f, 16f. In this case, the lamp operation is not different during its half cycle in the normal polarity, but, at the subsequent half cycle, the lamp 16 does not discharge, hence no current flows therein, at an instant when the switching device *A* is interrupted (corresponding to t_1 in Figure 32(e)), whereby a high voltage tends to be applied to the switching device *A*. At this instant, a charging current flows in the surge absorbing circuit 37 to restrain this high voltage. While it is possible to contemplate various other construction for the surge absorbing circuit 37, it should contain therein at least a capacitor, a resistor serially connected with it, another resistor connected in parallel with it, and a diode. In this manner, the application of the high voltage to the switching device *A* can be prevented by means of the surge absorbing circuit.

In the case of the output transformer being the leakage type transformer, the surge absorbing circuit 37 may be constructed as in the above-described embodiment with respect to the secondary winding 18S; besides this, the circuit may be connected with the secondary winding through a middle point as shown in Figure 34, or it may be connected with another winding of the secondary winding which is further provided at the secondary side.

Further, the connection of the surge absorbing circuit 37 in parallel with the switching device *A* as in the fifteenth embodiment shown in Figure 33 is effective not only in the case of connecting the inductive impedance in series with the switching device *A* (the device construction as shown in Figure 23), but also in the case of further connecting an auxiliary choking coil, etc. in parallel with the lamp and in series with the switching device *A*.

Besides the device shown in this embodiment, the inverter may be of such a construction that it is able to generate a substantially sinusoidal output and to supply a high frequency power having a pause-time period to the lamp, and that the main impedance for limiting the lamp current in the inverter is constructed with the inductive reactance. Moreover, the input d.c. voltage to the inverter may not necessarily be one which has been rectified and smoothed by the smoothing capacitor as in the foregoing embodiments, but it may be those such as pulsating current obtained without provision of the smoothing capacitor 14 or its equivalent component, or one obtained by using an appropriate auxilairy d.c. power source at this portion for the smoothing capacitor.

Furthermore, in the above-described fifteenth embodiment of the present invention, there has been indicated use of the current transformer 33 as the method for setting the pause-time period, but the invention may of course be applicable to the use of other expedient for realizing the pause-time period.

The switching device *A* may utilize various switching elements such as, for example, a field-effect transistor, etc. The method for connecting the switching device *A* may be of variety when the output transformer is the leakage type transformer, though any type of the connecting method is possible, provided that a desired high frequency power can be supplied. It is further feasible to combine it with an expedient for properly controlling the switching device *A* and also performing starting and preheating operations of the lamp.

In the following, explanations will be given as to the nineteenth embodiment of the present invention in relation to the twelfth embodiment shown in Figure 23. Before explaining the nineteenth embodiment, the operations of the lighting circuit according to the twelfth embodiment will be explained in further details.

The circuit of this twelfth embodiment has such an advantage that the instantaneous value A_1 of the lamp current when the current begins to flow in the lamp 16 remains to be a constant value irrespective of variations in the power source voltage, etc., although, on the other hand, the

circuit is supposed to have an inconvenience to be mentioned as follows. That is to say, when it is considered that the input d.c. voltage of the inverter 15 contains many ripples, for example, when the voltage as shown in Figures 25(a) and 25(c) is generated in the inverter 15, the peak value of the lamp current is also high during a period wherein the peak value of the output voltage is high, and the period T_{1a} (refer to Figure 22) during which the current flows through the lamp 16 becomes also long. On account of this, when the a.c. power source 12 increases, the power consumption of the lamp 16 increases much higher than the power source to thereby deteriorate the so-called "power source voltage variation characteristic"; and when the input d.c. voltage of the inverter 15 contains many ripples, even if the a.c. power source does not vary, the power consumption in the lamp at every half cycle of the high frequency inevitably varies to a large extent, and some other problems.

Under such circumstances, there has further been contemplated the lighting circuit as shown in Figure 35 paying attention to the abovementioned point.

Figure 35 illustrates the control device 19 for the lighting circuit for the electric discharge lamp as the nineteenth embodiment of the present invention, the control device being applicable to the lighting circuit such as, for example, shown in Figure 23. The control device as shown in Figure 35 is constructed with the current transformer 33, the resistor 34, the full-wave rectifying circuit 35, resistors 44, 45 for detecting and dividing voltage of the inverter output current at every half cycle, the diode 39, the capacitor 40, the resistor 41, the constant voltage diode 42, the resistor 43, the voltage comparator 46, the resistor 47, the auxiliary d.c. power source for driving 36, and the transistor 25 for the switching device *A*. Incidentally, the terminal voltage of the capacitor 40 assumes a voltage analogous to an envelope of the peak value of the output current from the inverter 15 or to the input d.c. voltage into the inverter 15.

In the following, explanations will be given as to the operations of the control device 19 of the above-described construction, when it is used for the lighting circuit for the electric discharge lamp as shown in Figure 21. Assume now that the inverter 15 starts its operation, and the lamp 16 is operated. Then, there is applied to the input terminal B of the voltage comparator 46 a varying voltage of the peak value envelope of the output from the inverter as shown in Figure 36(a) by the signal produced in the current transformer 33. Also, there is applied to the input terminal A of the voltage comparator 46 a voltage analogous to the high frequency output current as shown by a broken line in Figure 36(a). In this way, the voltage comparator 46 has its output transistor rendered conductive during a period of the voltage at the input terminal A becoming higher than the voltage at the input terminal B thereof, i.e., during the periods of D_1 and D_2 as shown in Figure 36(b), and the output terminal C assumes a low voltage level (as shown in Figure 36(c)). Accordingly, the transistor 25 becomes non-conductive during the periods D_1 and D_2, and the current flows to the side of the lamp 16. Here, as is apparent from the state of the voltage at the terminal B, it is possible to prevent the period, during which the current flows through the lamp 16, from extending, even when the peak value of the output current from the inverter is large in comparison with a case wherein the peak is small, i.e., a relationship of $D_1 \ll D_2$. Further, the period D_1 during which the peak value is small and the period D_2 during which the peak value is large can be appropriately set by selection of a voltage dividing ratio of the resistors 44, 45 and a zener voltage in the constant voltage diode 42.

In the above-described embodiment, the control of the device is effected in correspondence to the peak value of the output current from the inverter. It may however be feasible to effect the control in accordance with the input voltage for the inverter 15 by such means that, for example, a high frequency component is eliminated from the output voltage in the winding provided on the transformer 18 for the inverter 15, and the output voltage is rectified and applied to the input terminal B of the voltage comparator 46. It is also feasible that, in the state of the peak value of the output current from the inverter being lower than a predetermined value, as, for example, in the period during which the peak value is lower than the current value A_L in Figures 25(b) and 25(d), the lamp current be so set that no pause-time period be provided therein.

In the foregoing explanations, use of the current transformer 33 in the control device 19 has been taken as an example, although other expedient may of course, be adopted, such as, for example, detection of current by use of a resistor, etc. Furthermore, a period during which the current is supplied to the lamp is set by use of the voltage comparator 46, which may also be carried out by other expedients. Moreover, in the above-described embodiment, the switching device *A* is a combination of the rectifying circuit 24 and the transistor 25, although the same effect can be obtained by use of the field-effect transistor, and other switching elements.

The inverter 15 may be of any type that is able to obtain a substantially sinusoidal output voltage at its output terminal, such as, for example, a serial inverter or a bridge type inverter provided with an output transformer. The current limiting impedance 23 for setting the lamp current at a predetermined value may not only be the inductance of the inductive reactance, but also the capacitance of the capacitive reactance.

In the above explanations, use of the choking coil 23 at the output terminal of the inverter 15 is taken as an example. However, the transformer 18 of the inverter 15 may also be constructed as the leakage type transformer.

The arrangement of the switching device *A* is possible other than that shown in the above-

described embodiment. That is to say, an additional winding having an opposite polarity to that of the secondary winding 18S of the transformer 18 is provided, by way of which the switching device *A* is connected, or, in the case of the transformer 18 being the leakage type transformer, an intermediate tap is provided on the secondary winding and the switching device *A* is connected with a low pressure cable way to be formed by this intermediate tap. Or, it may also be feasible that an impedance is connected in series with the switching device *A* to thereby reduce the current flowing in the switching device. Furthermore, it may be feasible that the switching device *A* is connected in parallel with the lamp 16 through the electrodes 16f, 16f and the preheating current is caused to flow through it at the time of its conduction. Also, with a view to stabilizing the switching device even after starting of the electric discharge, when the lamp 16 is being operated, there may be added an expedient to maintain the switching device *A* without its being operated for some length of time. This can be realized by providing a timer circuit to maintain the output at the output terminal C of the voltage comparator 46 in the embodiment shown in Figure 35 at a low output level during a predetermined period after closure of the power source, or by providing means for detecting the operating of the lamp 16 to control the output at the abovementioned output terminal C.

Besides using the rectified and smoothed voltage as the power source for the device as shown in Figure 1, the input d.c. voltage for the inverter 15 may also be the pulsating d.c. voltage as shown in Figure 25(a), or the d.c. voltage as shown in Figure 25(c) which is not perfectly smoothed, but obtained from the circuit constructed in combination with an appropriate d.c. power source, and so forth.

In the following, the twentieth embodiment of the lighting circuit according to the present invention will be described in reference to Figure 37. In this embodiment, the period for supplying electric current to the lamp is maintained substantially constant irrespective of magnitude of the output current from the inverter or instantaneous variations in the input d.c. voltage for the inverter, thereby reducing variations in the power consumption in the lamp at every half cycle.

In the following, the twentieth embodiment of the present invention will be explained in reference to the drawing. In Figure 37, the control device 19 is constructed, in addition to the full-wave rectifier 35 and the d.c. power source 36, the resistors 39 and 40, a transistor 41 having an output terminal L, monostable multi-vibrators 42, 43, each having an output terminal M and N and generating an output for a predetermined time period, resistors 44, 45 and 46, capacitors 47 and 48, and a transistor 49, thereby performing the drive-control of the transistors 25 in the switching device *A*.

Figures 38(a) to 38(f) respectively indicate signals corresponding to the output terminals K to O shown in Figure 37. Figure 38(f) shows the output current from the inverter 15, in which the hatch-lined portion designates the current flowing in the lamp 16. Assume now that the inverter 15 generates a high frequency voltage and the lamp 16 commences the electric discharge.

The output current from the inverter 15 flows in either switching device *A* or the lamp 16, and voltage resulted from the full-wave rectification of the output voltage from the current transformer 33 is as shown in Figure 36(a). During a period when the instantaneous value of this voltage is low, the transistor 41 is interrupted, and a synchronous signal as shown in Figure 38(b) is obtained at the output terminal L. Here, the monostable multi-vibrators 42, 43 are of the type which is triggered by the trailing part (shown by an arrow ↓ in the drawing) of the input signal and performs the time limiting operation. Accordingly, the monostable multi-vibrators 42, 43 perform their predetermined time-limiting operation, whereby the output voltages as shown in Figures 38(c) and 38(d) are generated at their respective output terminals M and N. These voltages are reversed by the transistor 49, while the output from the output terminal O becomes as shown in Figure 38(e), to drive the transistor 25 of the switching device *A*, whereby the current in the hatch-lined portion of Figure 38(f) flows through the lamp 16. Since the period of this current flow is determined by the time-limiting operation of the monostable multi-vibrator 43, it can be maintained at a substantially constant level irrespective of the output current from the inverter 15.

Though, in the above-described embodiment, the synchronous signal is generated by use of the current transformer 33, there may be used any other means which is capable of operating the switching device *A* so that the current flowing in the lamp 16 may include therein the peak value and its vicinity of the output current from the inverter. 15, and of being operated for a substantially constant time period. Further, while the switching device *A* according to this embodiment is a combination of the rectifying circuit 24 and the transistor 25, the same effect can be obtained by use of a field-effect transistor, or other switching elements. Furthermore, the connection of the switching device *A* can be effected by other method than the above-described embodiment. For instance, an additional winding having the opposite polarity to that of the secondary winding 18S of the transformer is provided, by way of which the switching device *A* is connected, or, in the case of the transformer 18 being constructed as the leakage type transformer without use of the choking coil 23, an intermediate tap is provided in the secondary winding 18S and the switching device A is connected with a low pressure cable way to be formed by this intermediate tap, or other winding may be made the low voltage cable way. Furthermore, it is also feasible to connect impedance in series with the switching device A so as to reduce the current flowing in the switching device *A*. It is moreover feasible that the

switching device *A* is connected in parallel with the lamp 16 through the electrodes 16f, 16f and the preheating current is caused to flow at the time of its conduction. Also, with a view to preheating the electrodes 16f, 16f at the start of the lamp 16 and facilitating commencement of the electric discharge, there may be added an expedient to differentiate the conduction and interruption operations of the switching device *A* from those operations at the time of the normal operating. Besides using the rectified and smoothed power source as in the above-described embodiment, the input d.c. voltage for the inverter 15 may use a pulsating d.c. voltage as shown in Figure 25(a), or a d.c. voltage obtained from a circuit constructed in combination with an appropriate auxiliary power source of low peak value as shown in Figure 25(c). It is also feasible that, in the case of a voltage containing therein many ripples as such, the switching device *A* is kept in the interrupted state with the cycle having its peak value lower than a certain current value A_L as shown in Figure 25(d) by detecting the voltage level at the terminal K and controlling the transistor 49, and that the device of the present invention is operated with the cycle alone having the peak value higher than the current value A_L. Conversely, when the switching device *A* is operated only during a period of lower peak value than the current value A_L, the switching device may be of a low voltage withstand. On the other hand, it may be sufficient that the inverter 15 is of such a type that generates a substantially sinusoidal output voltage at the output terminal thereof, and uses the capacitive or inductive reactance as the current limiting impedance to set the lamp current. As an example, a serial inverter or a bridge type inverter provided with the output transformer is also useful.

In the following, explanations will be made as to the twenty-first embodiment of the lighting circuit according to the present invention in relation to the fourteenth embodiment of the circuit shown in Figure 25. This embodiment is of a such a construction that, when the lamp does not perform its normal electric discharge, the switching device connected in parallel with the lamp is conducted and maintained to thereby prevent application of the surge voltage to the switching device or generation of excessive inverter current.

Referring now to Figure 39, the lighting circuit according to the twenty-first embodiment of the invention will be described. Figure 39 illustrates the construction of the lighting circuit according to the present embodiment, in which a point of difference from the fourteenth embodiment in Figure 27 resides in that no choking coil is provided. Figure 40 shows the construction of the control device 19 for use in the circuit of Figure 39, which comprises resistors 34, 37, 39 and 42, the constant voltage diode 35, the capacitors 33, 36, the thyrister 38, the diodes 40, 43, and the transistor 41.

In the above-described construction, when the lamp 16 is operating in its normal condition, the voltage in the control winding 18d is as shown by a solid line in Figure 41. When the output voltage from the full-wave rectifier 27 becomes higher than a set voltage V_{29} in the constant voltage diode 29, the transistor 30 becomes conductive, and, after a predetermined time to be decided by the resistor 31 and the capacitor 33, the transistor 25 is interrupted, whereby the output current in the inverter 15 flow through the lamp 16. Also, when the output voltage from the full-wave rectifier 27 becomes lower than the set voltage V_{29}, the transistor 30 is interrupted, the transistor 25 becomes conductive, and the current does not flow through the lamp 16. On the contrary, when the lamp 16 is in an abnormal condition such as, for example, no discharging or the asymmetrical discharging due to the end of its service life, the voltage in the control winding 18d becomes higher as shown by a dot line in Figure 41 than the voltage during its normal operation (shown by the solid line); in particular, in its asymmetrical discharging, the voltage increases from its normal voltage level at either positive or negative polarity in the waveform as shown in Figure 41. In this way, when the output voltage from the full-wave rectifier 27 becomes higher than a set voltage V_{35} in the constant voltage diode 35, the thyristor 38 becomes conductive and the transistor 41 is interrupted. On account of this, the base current continues to flow in the transistor 25 through the resistor 42, and the transistor 25 maintains its conductive state, whereby a high voltage is no longer applied to the lamp 16. As the result of this, increase in current and voltage due to the asymmetrical discharging and generation of the high surge voltage at the time of non-lighting of the lamp are prevented. The capacitor 36 and the resistor 37 function to prevent the thyristor 38 from becoming conductive at the time of the operating of the lamp 16, either at the initial stage of its operating or until commencement of its operating.

Incidentally, in the above-described embodiment, when the thyristor 38 becomes once conductive, this conductive state is maintained; however, after lapse of a predetermined time period using a timer, etc., the switching device *A* may be reinstated to its interrupted state. The current to flow during maintenance of the switching device *A* in its conductive state may be set at a value which is not very much different from that during the operating of the lamp by setting the leakage inductance of the output leakage transformer 18 in the inverter 15; however, it is also feasible to provide the impedance 26 as has been done heretofore. As the preheating method of the lamp electrode 16f, it is also useful that the switching device *A* is connected in parallel with the lamp 16 through its filament; at the time of operating of the lamp, the conduction period of the switching device *A* is extended (or the interruption period T, may be eliminated) to sufficiently preheat the filament, thereafter, the period T_0 is made shorter (or may be eliminated) to facilitate commencement of the electric discharge in the lamp 16; and

after the operating, the periods T_0 and T_1 are reinstated to their original set values. In the foregoing explanation, use is made of the voltage in the control winding 18d wound at the secondary side of the leakage type output transformer 18 as the input signal into the control device 19. This object can be achieved by use of a voltage substantially analogous to the voltage across the lamp 16: for example, a signal generating transformer is connected in parallel with the lamp 16, and the voltage in the winding provided on this transformer is used as the input signal into the control device 19, in which case there may also be used a construction wherein the impedance 26 is connected. Next, where there is a phase difference between the input signal and the voltage across the terminals of the lamp 16, this phase difference may be compensated to subject the switching device *A* to the open and close controls. This can be realized, in the case of the leakage type transformer as in this embodiment, by appropriate adjustment of the winding position of the control winding 18d.

In this twenty-first embodiment of the present invention, the switching device *A* is operated by the voltage in the control winding 18d for both its normal and abnormal operations. However, it is also feasible that the normal operation is performed by, for example, detecting the current flowing in the inverter 15 or the lamp 16 to provide an appropriate pause-time period, and, at the abnormal operation, the switching device *A* is operated by obtaining a voltage substantially analogous to the voltage across the terminals of the lamp 16 as in this embodiment. Conversely, it is also feasible that other means be provided to cause the switching device to perform the operations in conformity to its normal operations and its abnormal operations by detection of the current flowing through the lamp 16 or of the output current from the inverter 15.

For the inverter 15, the self-oscillating push-pull inverter as used in this embodiment is suitable. Besides this, however, other types of the inverter may be used, which is capable of stopping the power supply to the lamp 16 at the rising part of a substantially sinusoidal output current at every half cycle thereof, and of supplying the power to the lamp at the maximum instantaneous value of the current or in its vicinity. The output transformer 18 may also not necessarily be of the leakage type. It is of course possible that, depending on the kind of the current limiting impedance of the lamp 16, when the impedance 26 connected in series with the switching device *A* is to be provided, the transformer may be constructed with a capacitor. From the standpoint of quicken the trailing of the current to be supplied to the lamp 16, the latter is preferable. Furthermore, when the choking coil is used as the impedance 26, it may be connected with the output side of the full-wave rectifying circuit 24.

For the auxiliary d.c. power source 14 to the inverter 15, there may be used a low d.c. voltage to be obtained by use of a transformer, etc., besides a well known smoothing circuit, or a d.c. voltage generated from a divided voltage due to the series connection of a plurality of capacitors, or other means. In short, the power source may contain therein the ripples, if only the required electric discharge of the lamp 16 can be maintained.

Furthermore, in the above-described embodiment, the switching device *A* is constructed with the rectifying circuit 24 and the transistor 25. However, it may be made up of other switching elements having the required characteristic. The connection of the switching device *A* can be done by other methods than the above-described one, provided that a power supply stoppage period to the lamp 16 can be provided.

So far the present invention has been described with reference to particular embodiments thereof, it should be noted that the present invention is not limited to these embodiments alone, but any changes and modifications may be made by those skilled in the art within the spirit and scope of the invention as recited in the appended claims.

Claims

1. A lighting circuit driven by an a.c. voltage source or a pulsating d.c. voltage source, for maintaining a low pressure electric discharge lamp in permanent operation, said circuit comprising a high frequency inverter (15), a transformer (18) having a primary winding (18a) connected to said frequency inverter (15) and a secondary winding (18s) connected to the electric discharge lamp (16), switching means (A) for repeatedly applying power to said lamp (16), and a control device (19) for determining the length of a duty cycle within each half cycle of the output voltage of said frequency inverter (15) during which said lamp (16) is provided with electric power, characterized by:

said frequency inverter (15) having a characteristic of rendering its output voltage to be in a substantially sinusoidal waveform,

said switching device (A) providing a short circuit for suppressing voltage being supplied to said lamp (16),

said control device (19) controlling said switching device (A) and being arranged to maintain said switching device (A) in its short circuiting condition during operation at the rising part of each half cycle of the transformer output voltage, and to render said switching device (A) open at a value of the transformer output voltage below and close to its maximum instantaneous value and maintained open until said voltage has passed and reached below but close to its maximum value, thereby providing an interruption period (T_1) during which power is applied to the discharge lamp (16).

2. The lighting circuit according to claim 1, characterized in that said high frequency inverter (15) is of a separately excited type. (Fig. 3).

3. The lighting circuit according to claim 1,

characterized in that said switching device (A) is provided in parallel with the low pressure electric discharge lamp (16). (Fig. 3).

4. The lighting circuit according to claim 1, 2 or 3, characterized in that said high frequency inverter (15) has a high frequency choking coil (17) at its input terminal. (Fig. 3).

5. The lighting circuit according to claim 4, characterized in that said high frequency inverter (15) is of a self-exciting type. (Fig. 3).

6. The lighting circuit according to any one of the claims 1 to 5, characterized in that the input voltage of said high frequency inverter (15) is a pulsating voltage obtained by full-wave rectification of alternating current voltage. (Fig. 3).

7. The lighting circuit according to claim 6, characterized in that an auxiliary power source (44) is provided to enable an output voltage to be obtained even when the alternating voltage is at the zero level. (Fig. 12).

8. The lighting circuit according to any one of claims 1 to 7, characterized in that at least one of the voltage and the current in the active elements of said high frequency inverter (15) is in a substantially sinusoidal waveform. (Fig. 10).

9. The lighting circuit as set forth in any one of claims 1 to 8, characterized by said inverter (15) having a leakage type output transformer (18), a high voltage cable way (F) provided at the secondary side of said output transformer (18) and to which said low pressure electric discharge lamp (16) is connected; a low voltage cable way (E) provided at the secondary side of said output transformer (18) and to which said switching device (A) is connected. (Fig. 15).

10. The lighting circuit according tm claim 9, characterized in that a current reducing impedance (33) is provided in series with the switching device (A) in said low voltage cable way (E), and that an impedance value of said current reducing impedance (33) is set in such a manner that a voltage to be generated in the high voltage cable way (F) in the time of conduction of said switching device (A) takes a value not reaching a discharge maintaining voltage of the low pressure electric discharge lamp (16). (Fig. 17).

11. The lighting circuit according to claim 9 or 10, characterized in that, when the low pressure electric discharge lamp (16) requires preheating of its electrodes (16f) at the time of operating, the electric conduction period in said switching device (A) at the initial stage of the operating is made longer than the electric conduction period at the time of its operating to thereby preheat said electrodes (16f), and, thereafter, the interruption period (T_1) of said switching device (A) is made longer than the interruption period at the time of operating the lamp (16) to thereby operate the low pressure electric discharge lamp (16). (Fig. 17).

12. The lighting circuit according to claim 10, characterized in that, when a pulsating d.c. voltage is used as the d.c. voltage source, the switching device (A) is so constructed that it maintains its interrupted state during a period when the maximum intantaneous value of the output current from said inverter (15) is below a predetermined value. (Fig. 23).

13. A lighting circuit as set forth in claim 1, characterized in that said control device (19) renders a voltage analogous to a voltage across the terminals of said low pressure electric discharge lamp (16) to be an input signal thereto, and controls to open and close said switching device (A) by comparing the input signal with a set value. (Fig. 27).

14. The lighting circuit according to claim 13, characterized in that said high frequency inverter (15) has a leakage type output transformer (18), that the secondary winding (18s) of the transformer and a control winding (18d) to generate an input signal for said control device (19) are provided in a magnetic circuit at the secondary side of said output transformer (18), and that said switching device (A) is connected with the secondary winding (18s) of said output transformer (18) through an impedance (26). (Fig. 27).

15. The lighting circuit according to claim 13 or 14, characterized in that, before said control device (19) commences the electric discharge in the low pressure electric discharge lamp (16) said switching device (A) is kept open for a period longer than at the time of operating the lamp (16). (Fig. 27).

16. The lighting circuit as set forth in any one of claims 1 to 15, characterized in that there is further provided at the output side of said inverter (15) a surge absorbing circuit (37) which absorbs a surge voltage generated at the time of interruption of said switching device (A), and that the charging operation of said surge absorbing circuit (37) is set at a time constant which terminates at substantially 3 μs or shorter at every half cycle of the high frequency voltage. (Fig. 33).

17. A lighting circuit as set forth in any one of claims 1 to 16, characterized in that the length of the interruption period (T_1) of said switching device (A) is maintained substantially constant during a normal operation time thereof. (Fig. 37).

18. The lighting circuit according to any one of claims 1 to 17, characterized in that said inverter (15) is a transistor inverter which performs self-oscillation. (Fig. 37).

19. The lighting circuit according to any one of claims 1 to 10, characterized in that said switching device (A) operates during a period when the input d.c. voltage to said inverter is at a low voltage level, and maintains its interruption condition during a period when the input d.c. voltage is at a high voltage level. (Fig. 37).

20. The lighting circuit according to any one of claims 1 to 10, characterized in that said switching device (A) operates during a period when the input d.c. voltage to said inverter (15) is at a high voltage level, and maintains its interruption state during a period when the input d.c. voltage is at a low voltage level. (Fig. 37).

21. A lighting circuit as set forth in any one of the preceding claims, characterized by detection means (18d), to detect no discharge or asymmet-

rical discharge from the electric discharge lamp (16), wherein said switching device (A) is so maintained conductive for at least a certain predetermined time in accordance with detection by said detection means (18d). (Fig. 39).

22. The lighting circuit according to claim 21, characterized in that said detection means comprises a control winding (18d) of said control device provided at the secondary side of a leakage type transformer (18). (Fig. 39).

Patentansprüche

1. Zündschaltung für eine elektrische Niederdruck-Gasentladungslampe, die von einer Wechselstromquelle oder einer pulsierenden Gleichstromquelle dauerbetrieben ist und umfaßt: einen Hochfrequenzinverter (15), einen Transformator (18), dessen primäre Wicklung (18a) an den Hochfrequenzinverter (15) und dessen sekundäre Wicklung (18s) an die elektrische Gasentladungslampe (16) angeschlossen sind, Schaltmittel (A) zum wiederholten Abgeben von Leistung an die Gasentladungslampe (16) und eine Überwachungseinrichtung (19), welche die Dauer eines Arbeitszyklus innerhalb jedes halben Zyklus der Ausgangsspannung des Hochfrequenzinverters (15) bestimmt, während dessen die Gastentladungslampe (16) mit elektrischer Energie versorgt ist, dadurch gekennzeichnet,

daß der Hochfrequenzinverter (15) so gestaltet ist, daß er eine im wesentlichen sinusförmige Ausgangsspannung abgibt,

daß die Schaltmittel (A) einen Kurzschluß bilden, um die der Gasentladungslampe (16) zugeführt Spannung zu unterdrücken,

daß die Überwachungseinrichtung (19) die Schaltmittel (A) überwacht derart, daß sie die Schaltmittel (A) während des Betriebs im ansteigenden Teil jeder Halbwelle der Ausgangsspannung des Transformators in der Kurzschlußstellung halten und die Schaltmittel (A) bei einem Wert der Transformatorspannung unterhalb ihres und nahe ihrem maximalen Momentanwert(es) öffnen und so lange geöffnet halten, bis die Ausgangsspannung ihren Maximalwert durchschritten hat und geringefügig darunter liegt, wodurch eine Unterbrechungszeitspanne (T_1) erzeugt wird, innerhalb welcher Leistung an die Gasentladungslampe (16) abgegeben wird.

2. Zündschaltung nach Anspruch 1, dadurch gekennzeichnet, daß der Hochfrequenzinverter (15) von separat zu erregender Bauart ist. (Figur 3).

3. Zünschaltung nach Anspruch 1, dadurch gekennzeichnet, daß die Schaltmittel (A) parallel zu der Niederdruck-Gastentladungslampe (16) liegen. (Figur 3).

4. Zündschaltung nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß eine Hochfrequenz-Selbstinduktionsspule (17) am Eingangsanschluß des Hochfrequenzinverters (15) liegt. (Figur 3).

5. Zündschaltung nach Ansrpuch 4, dadurch gekennzeichnet, daß der Hochfrequenzinverter (15) von selbsterregender Bauart ist. (Figur 3).

6. Zündschaltung nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Eingangsspannung des Hochfrequenzinverters (15) eine pulsierende Spannung ist, die durch Doppelweggleichrichtung einer Wechselspannung erhalten ist. (Figur 3).

7. Zündschaltung nach Anspruch 6, gekennzeichnet durch eine Hilfsleistungsquelle (44) die es ermöglicht, daß auch beim Nulldurchgang der Wechselspannung eine Ausgangsspannung erhalten wird. (Figur 12).

8. Zündschaltung nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß wenigstens die Spannung und/oder der Strom in den aktiven Elementen des Hochfrequenzinverters (15) im wesentlichen sinusförmigen Verlauf haben. (Figur 10).

9. Zündschaltung nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß der Hochfrequenzinverter (15) einen Ausgangs-Streutransformator (18) und eine Hochspannungsleitung (F) an der Sekundärseite des Ausgangs-Streutransformators (18) umfaßt, an die die Niederdrck-Gasentladungslqmpe (16) angeschlossen ist, und eine Niederspannungleitung (E) an der Sekundärseit des Ausgangs-Streutransformators (18) umfaßt, an die die Schaltmittel (A) angeschlossen sind. (Figur 15).

10. Zündschaltung nach Anspruch 9, gekennzeichnet durch eine Stromsenkimpedanz (33) in Reihe mit den Schaltmitteln (A) in der Niederspannungsleitung (E), wobei die Größe der Stromsenkimpedanz (33) so gewählt ist, daß eine in der Hochspannungsleitung (F) während des Durchschaltens der Schaltmittel (A) zu erzeugende Spannung einen Wert annimmt, der eine Spannung zum Aufrechterhalten der Entladung in der Niederdruck-Gasentladungslampe (16) nicht erreicht. (Figur 17).

11. Zündschaltung nach Anspruch 9 oder 10, dadurch gekennzeichnet, daß dann, wenn ein Vorheizen der Elektorden (16f) der Niederdruck-Gastentladungslampe (16) beim Betrieb vorgeheizt werden müssen, die Zeitspanne des Durchschaltens der Schaltmittel (A) zu Anfang des Betriebs länger ist als die Zeitspanne des Durchschaltens beim Betrieb, um die Elektroden (16f) vorzuheizen, und daß die Unterbrechungszeitspanne (T_1) der Schaltmittel (A) danach länger gemacht wird als die Unterbrechungszeitspanne während des Betriebs der Niederdruck-Gastentladungslampe (16), wodurch die Niederdruck-Gasentladungslampe (16) betrieben ist. (Figur 17).

12. Zündschaltung nach Anspruch 10, dadurch gekennzeichnet, daß dann, wenn eine pulsierde Gleichspannung als Gleichspannungsquelle verwendet ist, die Schaltmittel (A) so aufgebaut sind, daß sie während einer Zeitspanne, in der der maximale momentane Wert des Ausgangsstroms des Inverters (15) unter einem vorbestimmten Wert liegt, im Unterbrechungszustand bleiben. (Figur 23).

13. Zündschaltung nach Anspruch 1, dadurch gekennzeichnet, daß die Überwachungseinrichtung (19) eine Spannung abgeben, die der Span-

nung über den Anschlüssen der elektrischen Niederdruck-Gasentladungslampe (16) analog ist und ein Eingangssignal dazu darstellt, und das Öffnen und Schließen der Schaltmittel (A) durch Vergleichen des Eingangssignals mit einem vorgegebenen Wert steuern. (Figur 27).

14. Zündschaltung nach Anspruch 13, dadurch gekennzeichnet, daß der Hochfrequenzinverter (15) einen Ausgangs-Streutransformator (18) umfaßt, daß die Sekundärwicklung (18s) des Ausgangs-Streutransformators und eine Überwachungswicklung (18d) zum Erzeugen eines Eingangssignals für die Überwachungseinrichtung (19) in einem magnetischen Schaltkreis auf der Sekundärseite des Ausgangs-Steuetransformats (18) vorgesehen sind und daß die Schaltmittel (A) mit der Sekundärwicklung (18s) des Ausgangs-Streutransformators (18) über eine Impedanz (26) verbunden sind. (Figur 27).

15. Zündschaltung nach Anspruch 13 oder 14, dadurch gekennzeichnet, daß die Schaltmittel (A) für eine Zeitspanne offen gehalten werden, die länger als die Ansteuerungsperiode der Niederdruck-Gasentladungslampe (16) ist, bevor die Überwachungseinrichtung (19) mit der elektrischen Einlandung in der Niederdruck-Gastentladungslampe (16) beginnt. (Figur 27).

16. Zündschaltung nach einem der Ansprüche 1 bis 15, dadurch gekennzeichnet, daß an der Ausgangsseite des Hochfrequenzinverters (15) ein Überspannungsableit-Schaltkreis (37) vorgesehen ist, der eine während der Unterbrechung der Schaltmittel (A) erzeugte Überspannung ableitet, und daß für die Aufladung des Überspannungsableit-Schaltkreises (37) eine Zeitkonstante derart gewählt ist, daß die Aufladung im wesentlichen bei 3 µs oder früher in jeder Halbwelle der Hochfrequenzspannung endet. (Figur 33).

17. Zündschaltung nach einem der Ansprüche 1 bis 16, dadurch gekennzeichnet, daß die Dauer (T_1) der Unterbrechungszietspanne der Schaltmittel (A) während deren Normalbetriebs im wesentlichen konstant gehalten ist. (Figur 37).

18. Zündschaltung nach einem der Ansprüche 1 bis 17, dadurch gekennzeichnet, daß der Hochfrequenzinverter (15) ein Transistorinverter ist, der selbständig schwingt. (Figur 37).

19. Zündschaltung nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, daß die Schaltmittel (A) während einer Zeitspanne, in der die Eingangsgleichspannung an den Hochfrequenzinverter niedrig ist, arbeiten und während einer Zeitspanne, in der die Eingangsgleichspannung hoch ist, unterbrochen bleiben. (Figur 37).

20. Zündschaltung nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, daß die Schaltmittel (A) während einer Zeitspanne, in der die Eingangsleichspannung an den Hochfrequenzinverter (15) hoch ist, arbeiten und während einer Zeitspanne, in der die Eingangsgleichspannung niedrig ist, unterbrochen bleiben. (Figur 37).

21. Zündschaltung nach einem der vorangehenden Ansprüche, gekennzeichnet durch Erfassungsmittel (18d), zum Erfassen, ob die elektrische Niederdruck-Gastentladungslampe (16) nicht oder asymmetrisch entlädt, wobei die Schaltmittel (A) für mindestens eine vorbestimmte Periode entsprechend der Erfassung mittels der Erfassungsmittel (18d) leitend gehalten ist. (Figur 39).

22. Zündschaltung nach Anspruch 21, dadurch gekennzeichnet, daß die Erfassungsmittel eine Überwachungswicklung (18d) der Überwachungseinrichtung umfassen, die auf der Sekundärseite des Ausgangs-Streutransformators (18) angeordnet sind. (Figur 39).

Revendications

1. Circuit d'allumage, alimenté par une source de tension courant alternatif ou par une source de tension courant continu pulsatoire, pour maintenir en opération permanente une lampe à décharge électrique basse pression, ledit circuit comportant un onduleur haute fréquence (15), un transformateur (18) comprenant un bobinage primaire (18a) relié audit onduleur haute fréquence (15) et un bobinage secondaire (18s) relié à la lampe à décharge électrique (16), un moyen de commutation (A) pour appliquer de façon répétitive la puissance à ladite lampe (16) et un dispositif de commande (19) pour déterminer, à l'intérieur de chaque demi-cycle de la tension fournie par ledit onduleur haute fréquence (15), la longueur de l'intervalle de temps utile au cours duquel de la puissance électrique est fournie à ladite lampe (16), caractérisé

en ce que ledit onduleur haute fréquence (15) présente la caractéristique que sa tension de sortie a une forme d'onde sensiblement sinusoïdale,

en ce que ledit dispositif de commutation (A) provoque un court-circuit pour supprimer la tension fournie à ladite lampe (16),

en ce qu'un dispositif de commande (19) commande ledit dispositif de commutation (A) et en ce qu'il est conçu pour maintenir ledit dispositif de commutation (A) dans sa condition de court-circuit pendant que l'on se trouve sur la partie croissante de chaque demi-cycle de la tension de sortie du transformateur, et pour rendre ledit dispositif de commutation (A) non conducteur pour une valeur de la tension de sortie du transformateur inférieure à sa valeur instantanée maximale, mais très proche de cette valeur, et pour le maintenir non-conducteur jusqu'à ce que l'on soit passé au-delà de cette valeur inférieure à sa valeur instantanée maximale, mais très proche de cette valeur, créant ainsi une période (T_1) au cours de laquelle le dispositif de commutation est non-conducteur et au cours de laquelle la puissance électrique est fournie à la lampe à décharge (16).

2. Circuit d'allumage selon la revendication 1, caractérisé en ce que ledit onduleur haute fréquence (15) est du type à excitation séparée (figure 3).

3. Circuit d'allumage selon la revendication 1, caractérisé en ce que ledit dispositif de commutation (A) est monté en parallèle avec la lampe à décharge électrique basse pression (16) (figure 3).

4. Circuit d'allumage selon la revendication 1, 2 ou 3, caractérisé en ce que ledit onduleur haute fréquence (15) comprend à sa borne d'entrée une bobine d'arrêt haute fréquence (17) (figure 3).

5. Circuit d'allumage selon la revendication 4, caractérisé en ce que ledit onduleur haute fréquence (15) est du type auto-excité (figure 3).

6. Circuit d'allumage selon l'une quelconque des revendications 1 à 5, caractérisé en ce que la tension d'entrée dudit onduleur haute fréquence (15) est une tension pulsatoir obtenue en redressant sur double alternance la tension d'un courant alternatif (figure 3).

7. Circuit d'allumage selon la revendication 6, caractérisé en ce qu'il est prévu une source auxiliaire du puissance (44) pour permettre d'obtenir une tension de sortie même lorsque la tension alternative à la valeur zéro (figure 12).

8. Circuit d'allumage selon l'une quelconque des revendications 1 à 7, caractérisé en ce qu'au moins l'une des deux, de la tension et de l'intensité, dans les éléments actifs dudit onduleur haute fréquence (15), a une forme d'onde sensiblement sinusoïdale (figure 10).

9. Circuit d'allumage selon l'une quelconque des revendications 1 à 8, caractérisé en ce que ledit onduleur (15) comprend un transformateur de puissance (18) du type à fuite, un circuit haute tension (F) qui est prévu du côté secondaire dudit transformateur de puissance (18) et auquel est reliée ladite lampe à décharge électrique basse pression (16); ainsi qu'un circuit basse tension (E) qui est prévu du côté secondaire dudit transformateur de puissance (18) et auquel est relié ledit dispositif de commutation (A) (figure 15).

10. Circuit d'allumage selon la revendication 9, caractérisé en ce qu'une impédance de limitation de l'intensité (33) est montée en série avec le dispositif de commutation (A) dans ledit circuit basse tension (E); et en ce que l'on définit la valeur de ladite impédance de limitation de l'intensité (33) de façon telle qu'une tension à générer dans le circuit haute tension (F) au moment où ledit dispositif de commutation (A) est conducteur prend une valeur que n'atteint pas la tension de maintien de la décharge de la lampe à décharge électrique basse pression (16) (figure 17).

11. Circuit d'allumage selon la revendication 9 ou 10, caractérisé en ce que, si la lampe à décharge électrique basse pression (16) nécessite un préchauffage de ses électrodes (16f) au moment de fonctonner, on fait en sorte que la période pendant laquelle le dispositif de commutation (A) est conducteur à l'épape initiale du démarrage de la lampe soit plus longue que sa période de conduction au moment du fonctionnement de la lampe, pour, de ce fait, préchauffer lesdites électrodes (16f), et qu'ensuite la période (T_1) pendant laquelle ledit dispositif de commutation (A) est non-conducteur soit plus longue que la période pendant laquelle il est non-conducteur au moment du fonctionnement de la lampe (16), de façon que puisse fonctionner la lampe à décharge électrique basse pression (16) (figure 17).

12. Circuit d'allumage selon la revendication 10, caractérisé en ce que, si l'on utilise comme source de tension courant continu une tension courant continu plusatoire, le dispositif de commutation (A) est construit de façon à maintenir son état de non-conduction pendant la période pendant laquelle la valeur instantanée maximale de l'intensité fournie par ledit onduleur (15) est inférieure à une valeur prédéterminée (figure 23).

13. Circuit d'allumage selon la revendication 1, caractérisé en ce que ledit dispositif de commande (19) fait en sorte qu'une tension analogue à la tension qui existe aux bornes de ladite lampe à décharge électrique basse pression (16) constitue pour lui un signal d'entrée; et en ce qu'il commande la non-conduction et la conduction dudit dispositif de commutation (A) et comparant ce signal d'entrée avec une valeur prédéerminée (figure 27).

14. Circuit d'allumage selon la revendication 13, caractérisé en ce que ledit onduleur haute fréquence (15) comporte un transformateur de puissance (18) du type à fuite; en ce qu'il est prévu dans le circuit magnétique du côté secondaire dudit transformateur de puissance (18) un bobinage secondaire (18s) de ce transformateur et un bobinage de commande (18d) pour générer un signal d'entrée pour ledit dispositif de commande (19); et en ce que ledit dispositif de commutation (A) est relié au bobinage secondaire (18s) dudit transformateur de puissance (18) par l'intermédiaire d'une impédance (26) (figure 27).

15. Circuit d'allumage selon la revendication 13 ou 14, caractérisé en ce qu'avant que ledit dispositif de commande (19) commence la décharge électrique dans la lampe à décharge électrique basse pression (16), ledit dispositif de commutation (A) est maintenu non-conducteur pendant une période plus longue qu'au moment du fonctionnement de la lampe (16) (figure 27).

16. Circuit d'allumage selon l'une quelconque des revendications 1 à 15, caractérisé en ce qu'il est en outre prévu, du côté sortie dudit onduleur (15), un circuit (37) d'absorption des pointes qui absorbent une tension de pointe générée au moment où ledit dispositif de commutation (A) est non-conducteur; et en ce que l'opération de charge dudit circuit (37) d'absorption des pointes se fait en un temps constant sensiblement inférieur à 3 µm ou moins à chaque demi-cycle de la tension haute fréquence (figure 33).

17. Circuit d'allumage selon l'une quelconque des revendications 1 à 16, caractérisé en ce que la longueur de la période (T_1) pendant laquelle ledit dispositif de commutation (A) est non conducteur est maintenue sensiblement constante pendant son temps de fonctionnement normal (figure 37).

18. Circuit d'allumage selon l'une quelconque des revendications 1 à 17, caractérisé en ce que ledit onduleur (15) est un onduleur à transistor qui effectue une auto-oscillation (figure 37).

19. Circuit d'allumage selon l'une quelconque des revendications 1 à 10, caractérisé en ce que ledit dispositif de commutation (A) opère au cours de la période où la tension courant continu

d'entrée fournie audit onduleur est à un niveau bas, et maintient son état de non-conduction au cours de la période où la tension courant continu d'entrée est à un niveau haut (figure 37).

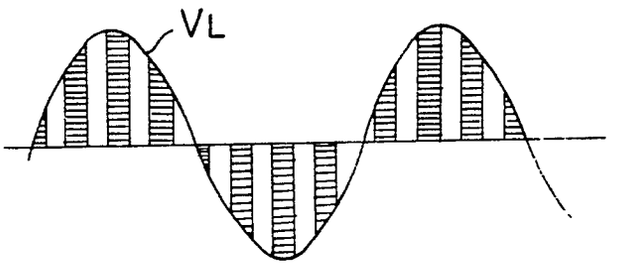
20. Circuit d'allumage selon l'une quelconque des revendications 1 à 10, caractérisé en ce que ledit dispositif de commutation (A) opère au cours de la période où la tension courant continu d'entrée fournie audit onduleur (15) est à un niveau haut, et maintient son état de non-conduction au cours de la période où la tension courant continu d'entrée est à un niveau bas (figure 37).

21. Circuit d'allumage selon l'une quelconque des revendications précédentes, caractérisé par un moyen de détection (18d) pour détecter l'absence de décharge ou l'existence d'une décharge dissymétrique dans la lampe à décharge électrique (16), étant précisé que ledit disposit de commutation (A) est maintenu conducteur pendant au moins une certain période de temps prédéterminée en accord avec la détection effectuée par ledit moyen de détection (18d) (figure 39).

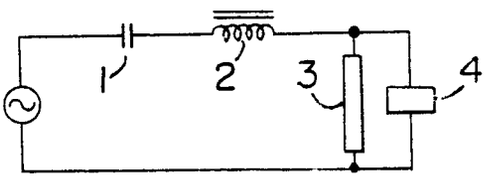
22. Circuit d'allumage selon la revendication 21, caractérisé en ce que ledit moyen de détection est constitué d'un bobinage de commande (18d) dudit dispositif de commande prévu du côté secondaire d'un transformateur du type à fuite (18) (figure 39).

FIGURE 1

(a)



(b)



(c)

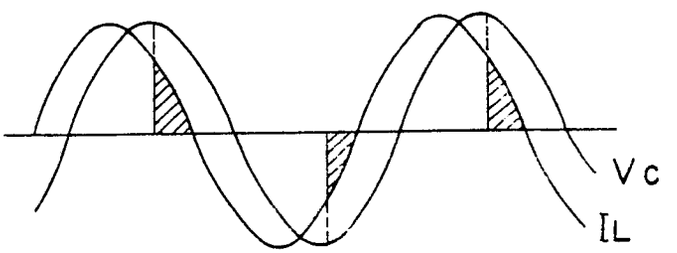
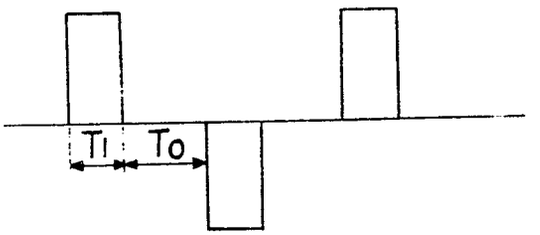


FIGURE 2

(a)



(b)

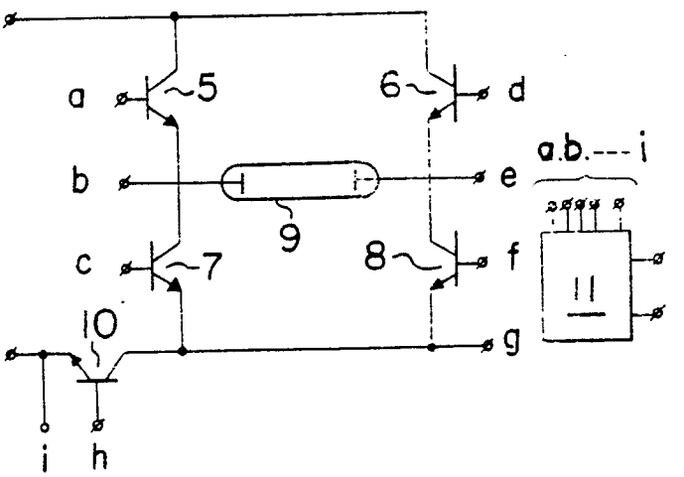


FIGURE 3

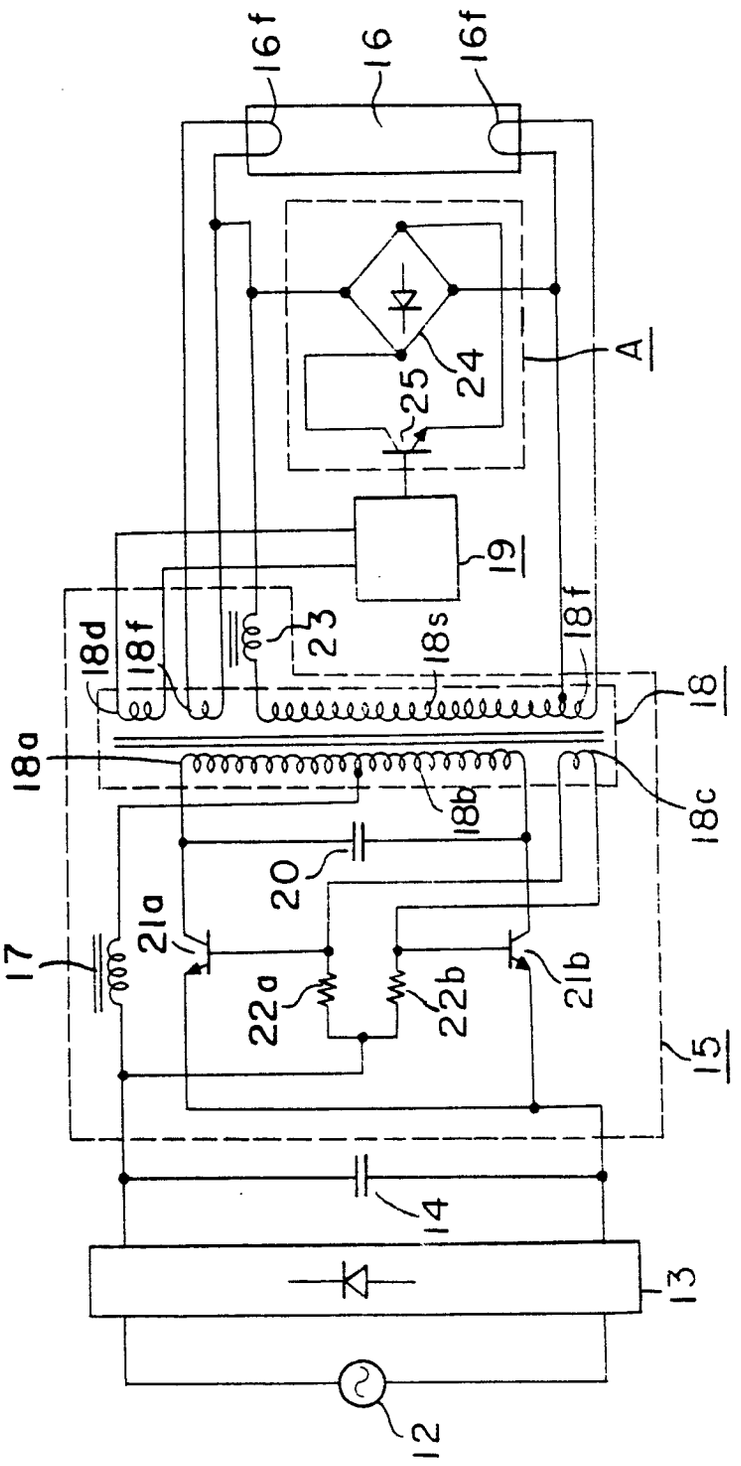

16f
16
16f
A
24
25
19
18d
18f
23
18s
18f
18
18a
18b
18c
20
21a
17
22a
22b
21b
15
14
13
12

FIGURE 4

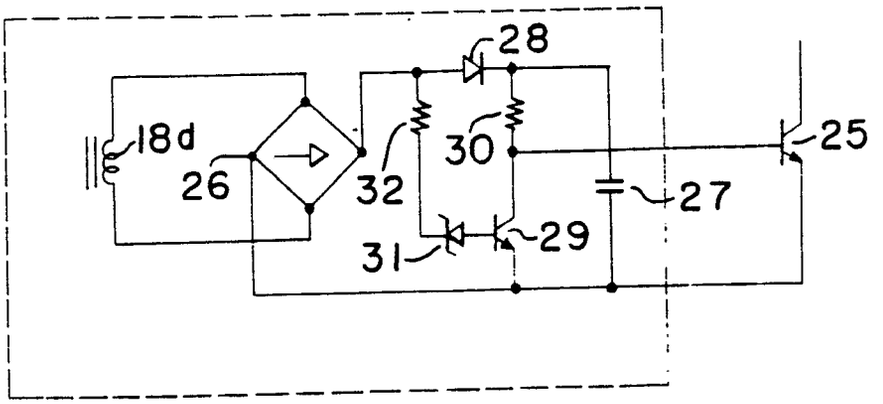


FIGURE 5

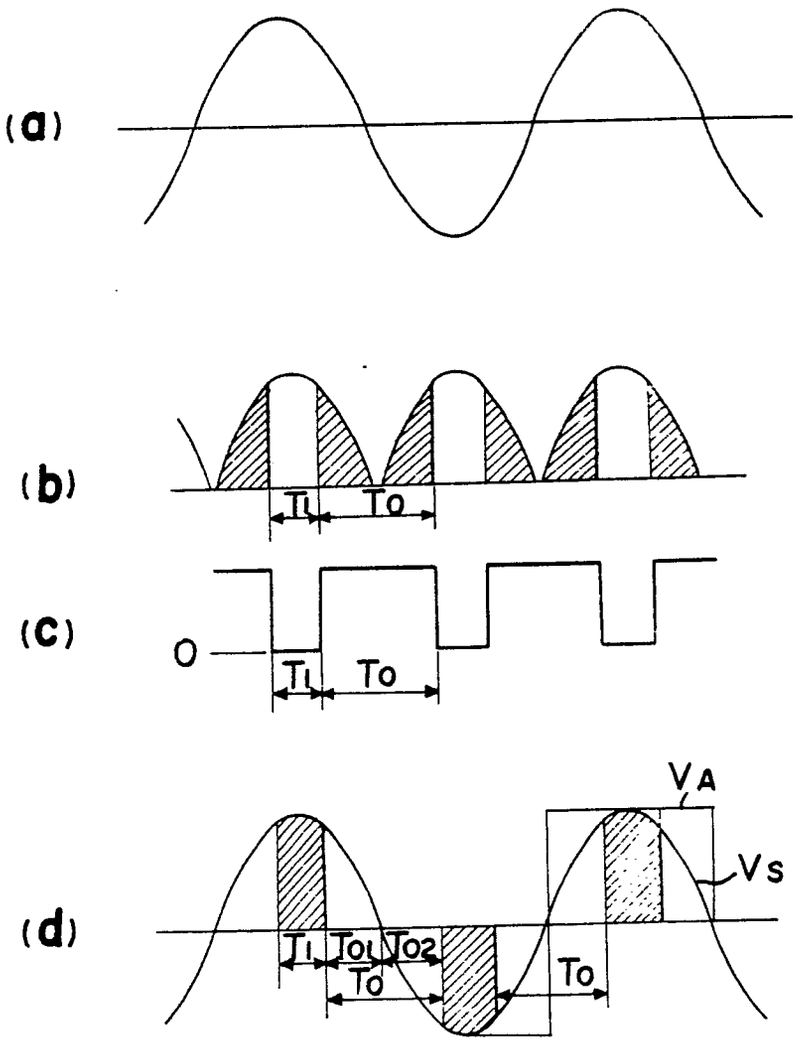


FIGURE 6

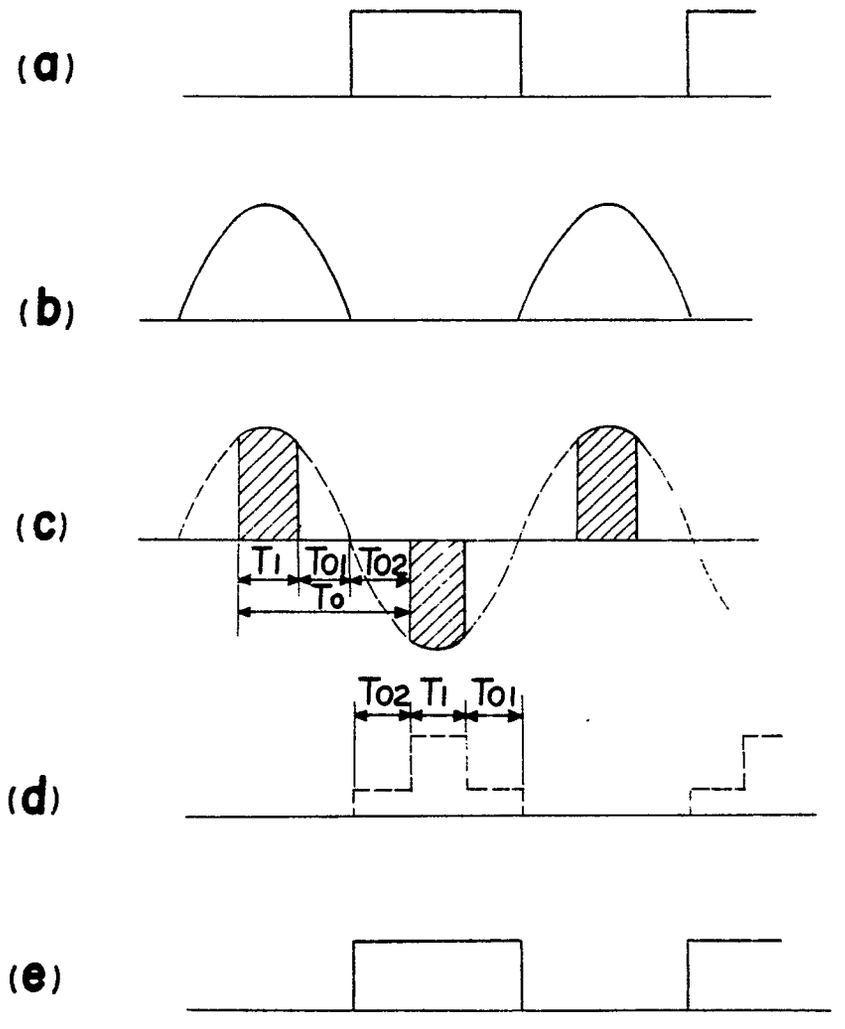


FIGURE 7

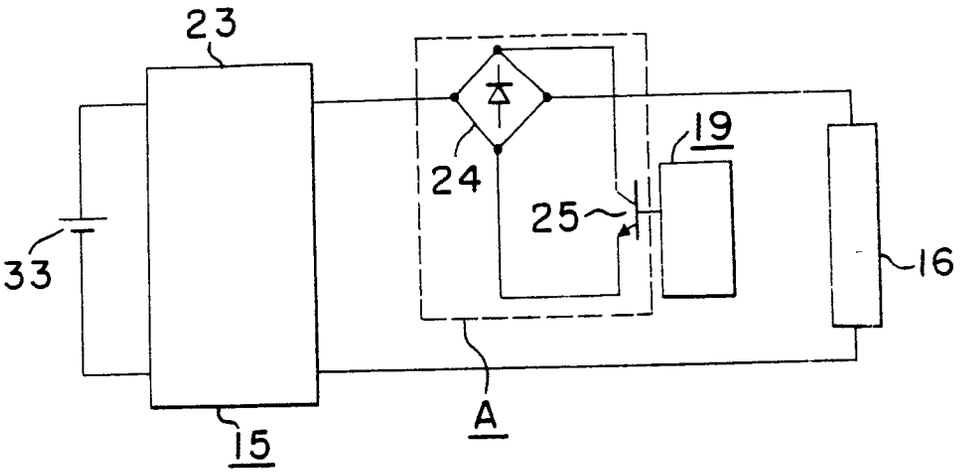


FIGURE 8

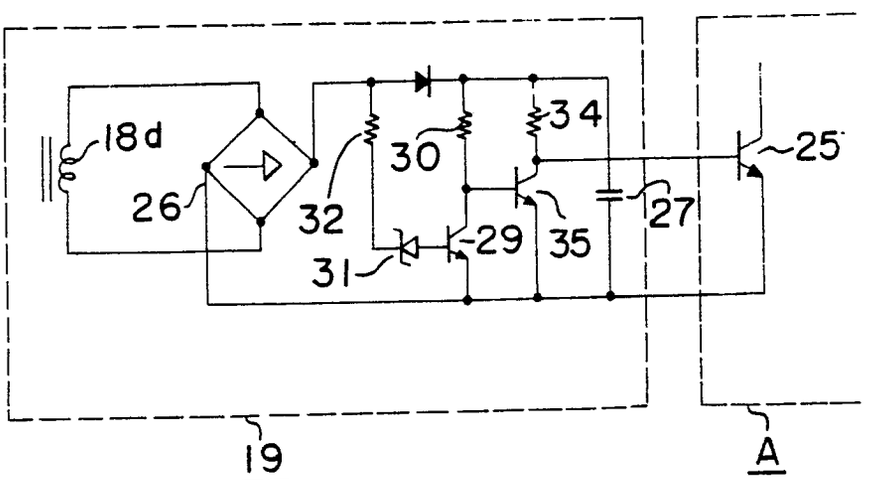


FIGURE 9

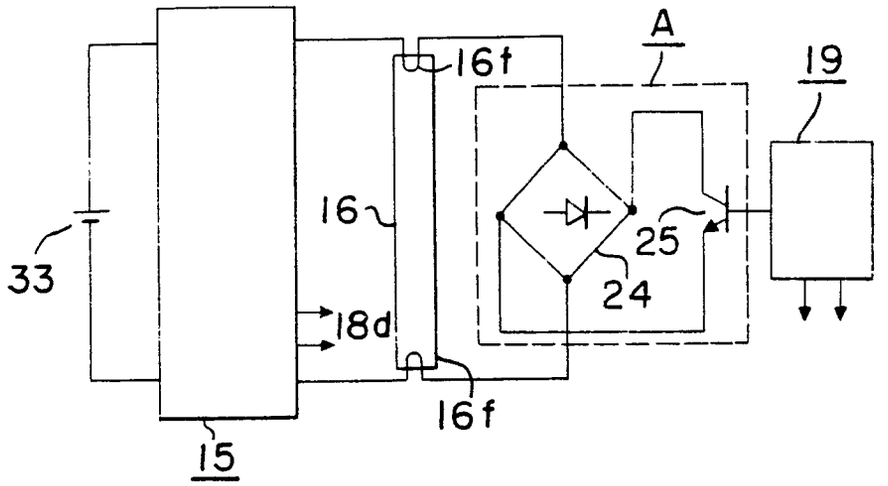


FIGURE 10

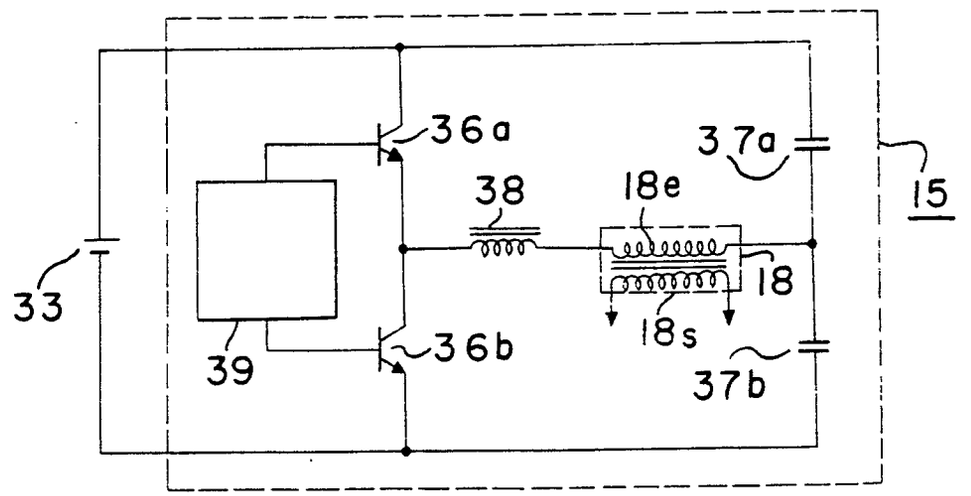


FIGURE 11

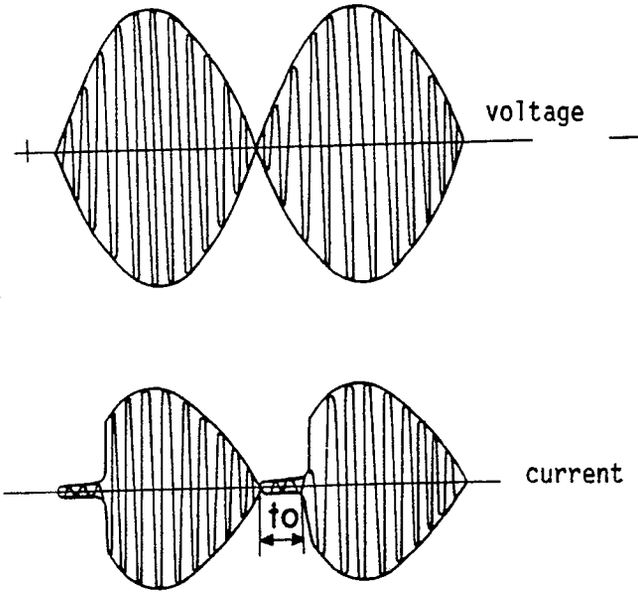


FIGURE 14

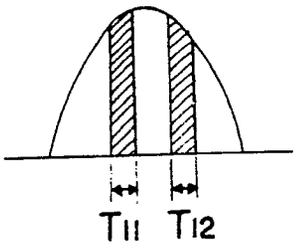


FIGURE 13

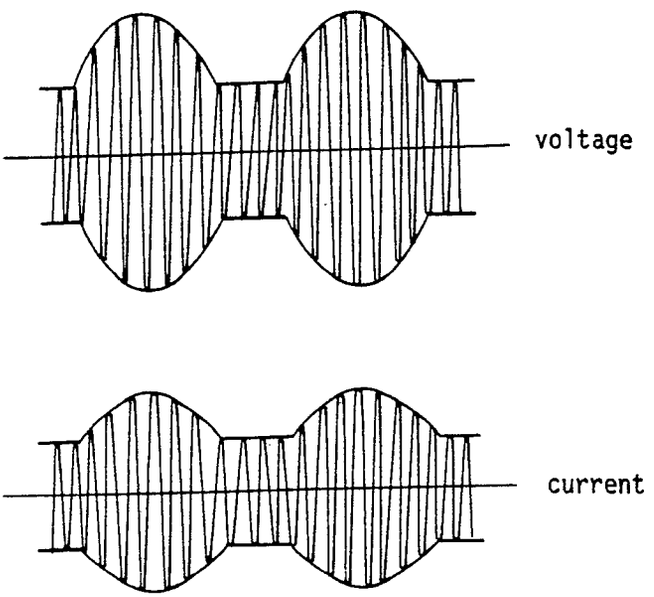


FIGURE 12

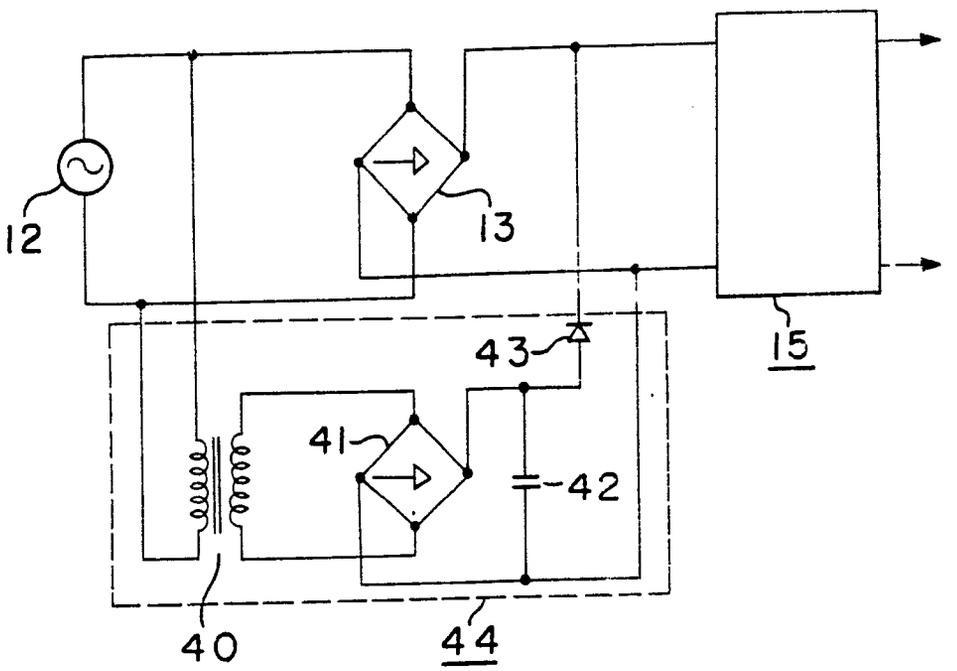


FIGURE 15

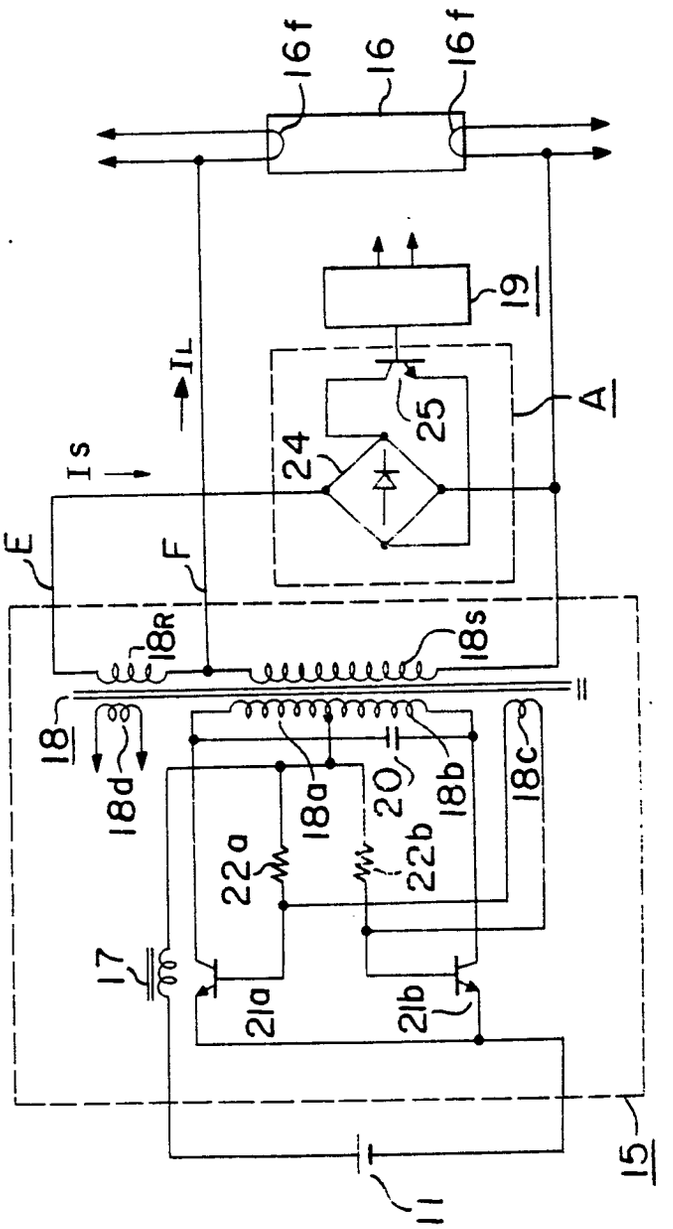

16f
16
16f
19
I_L
A
25
24
I_S
E
F
18R
18s
18
18d
18a
20
18b
18c
22a
22b
17
21a
21b
15
11

FIGURE 16

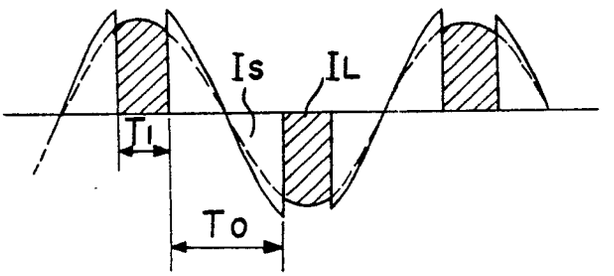


FIGURE 17

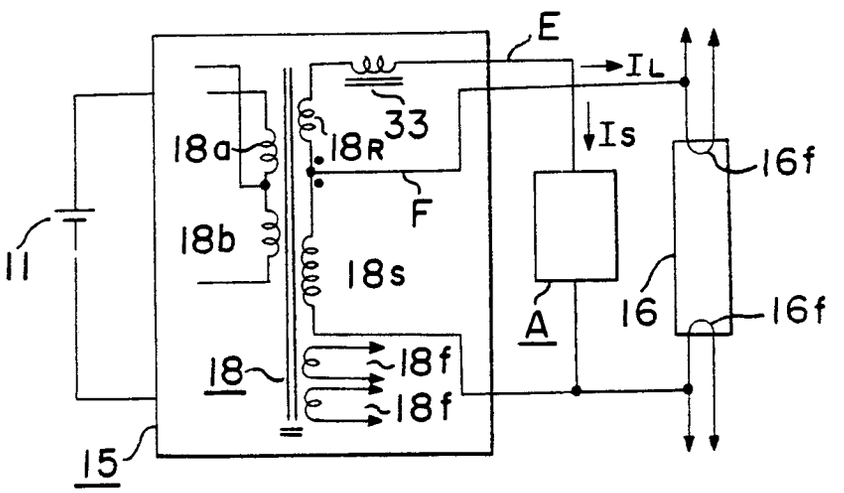


FIGURE 18

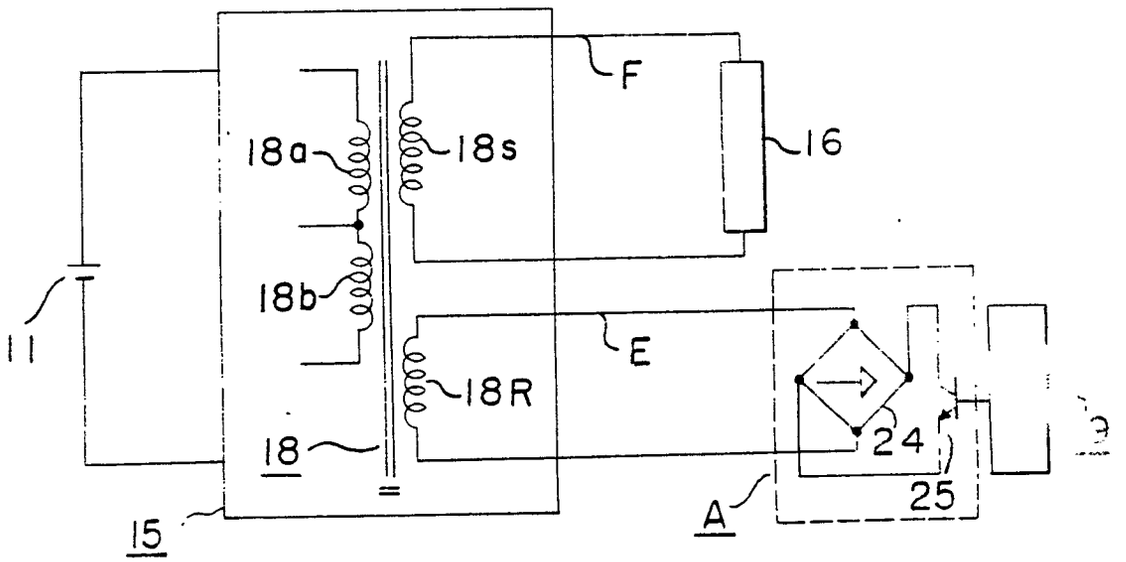


FIGURE 19

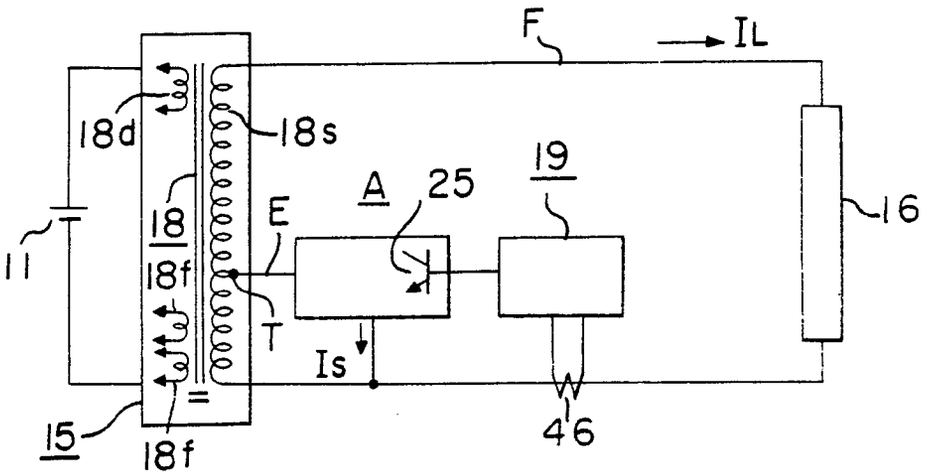


FIGURE 20

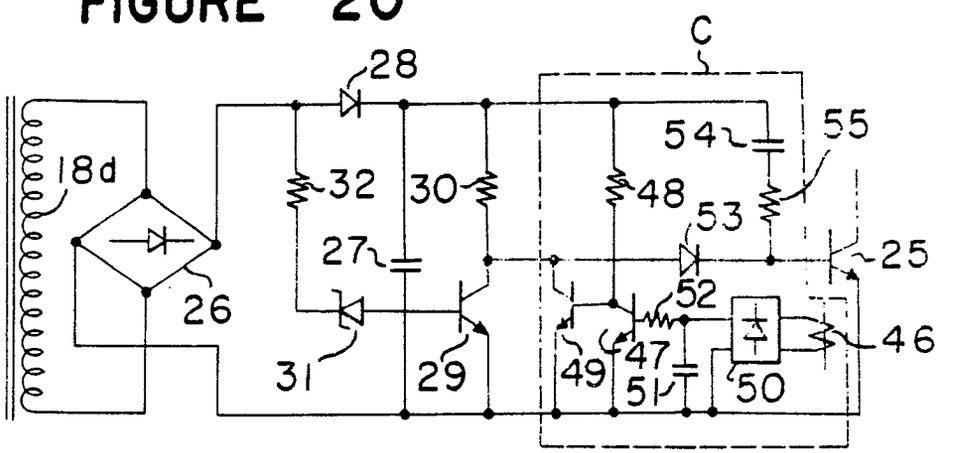


FIGURE 21

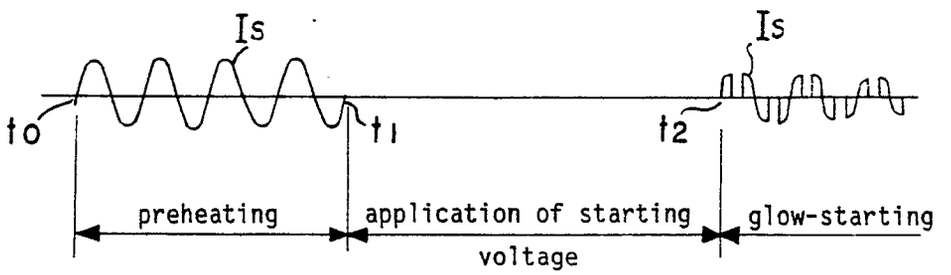


FIGURE 22

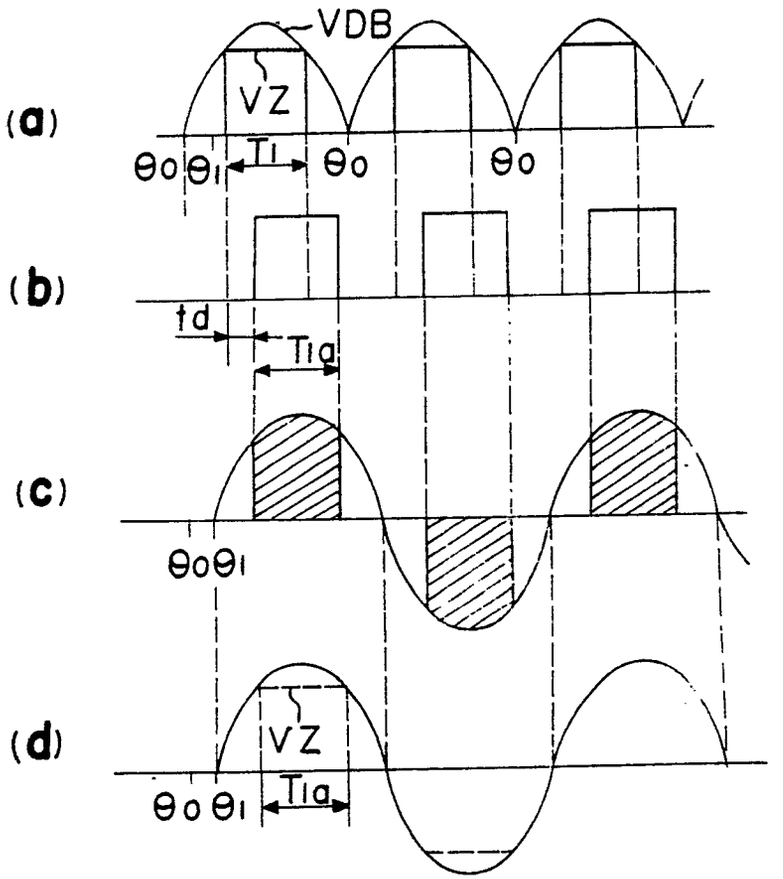


FIGURE 23

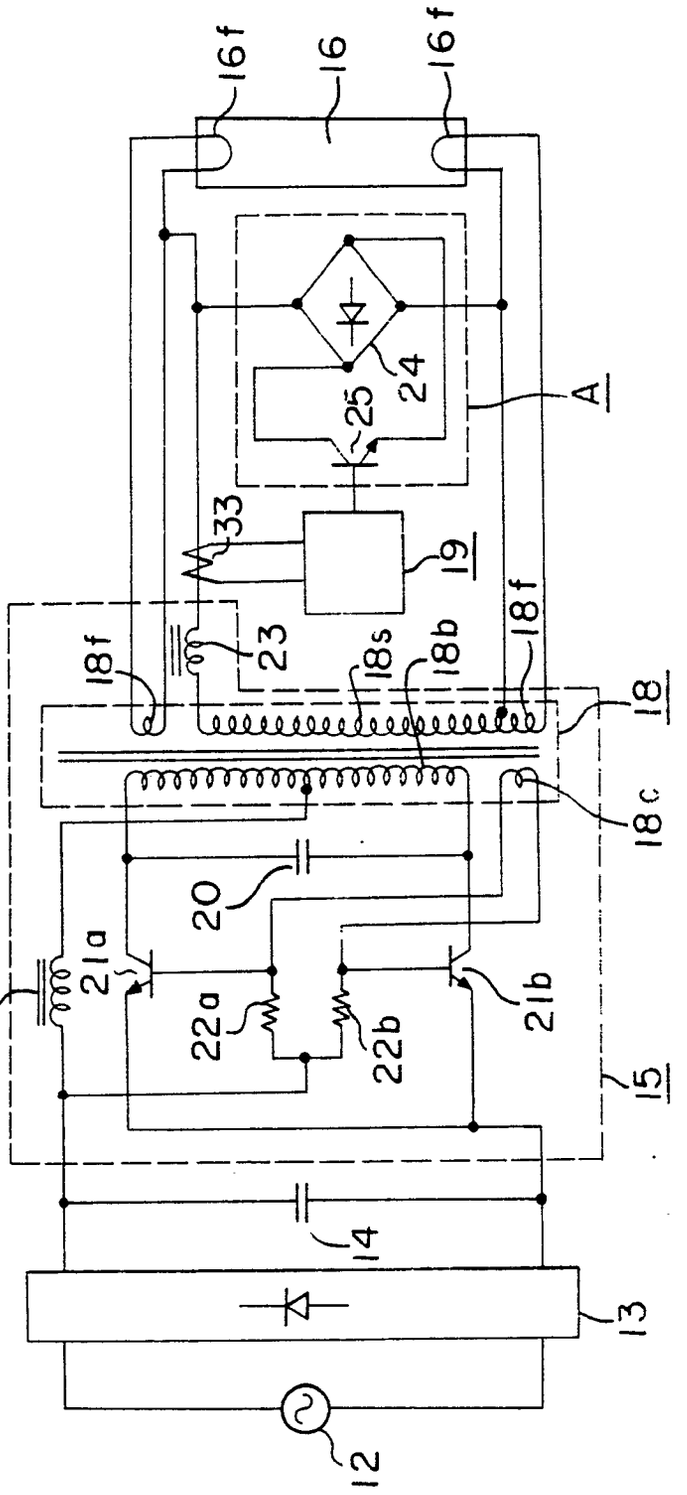

16f
16
16f
24
25
A
33
19
18f
23
18f
18s
18b
18
18c
20
17
21a
22a
22b
21b
15
14
13
12

FIGURE 24

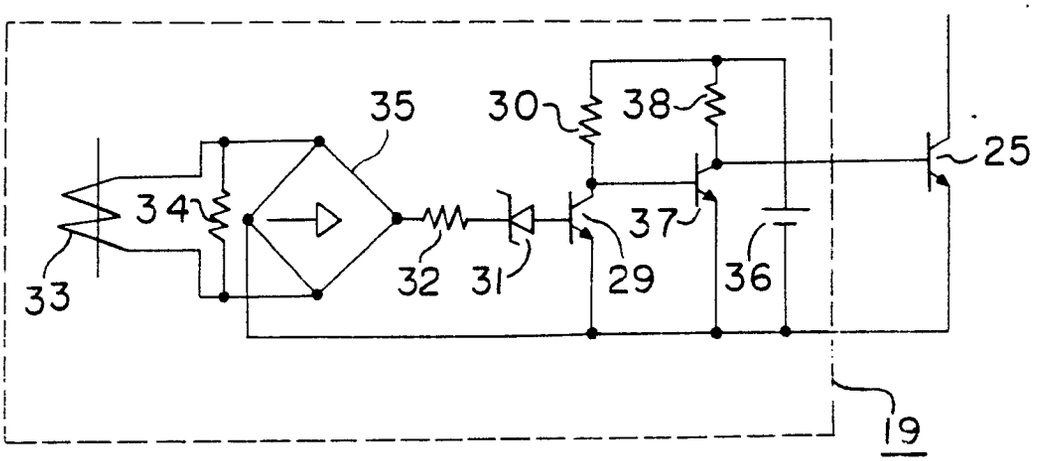
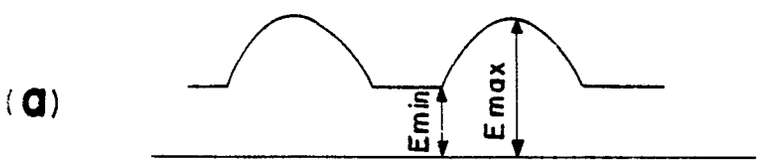
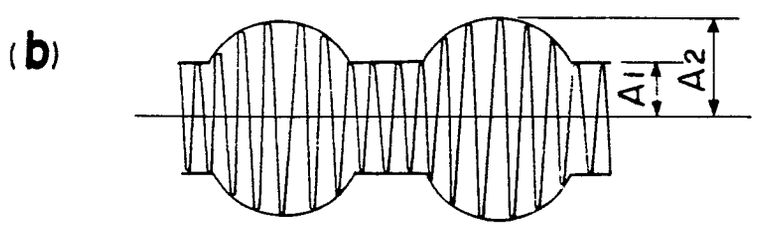


FIGURE 26





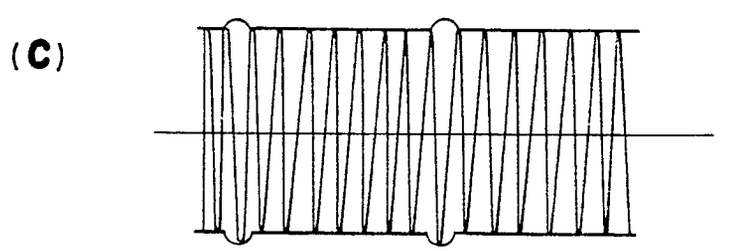


FIGURE 25

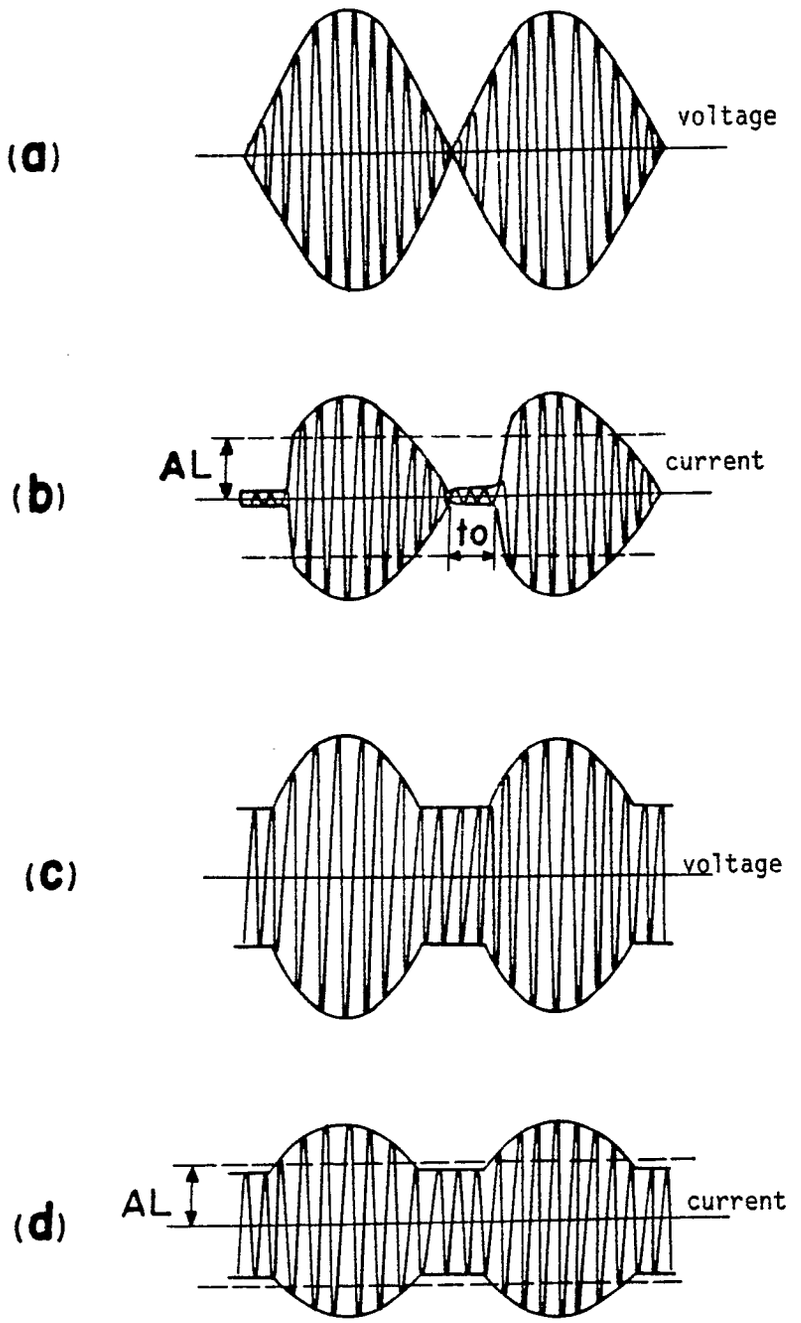


FIGURE 27

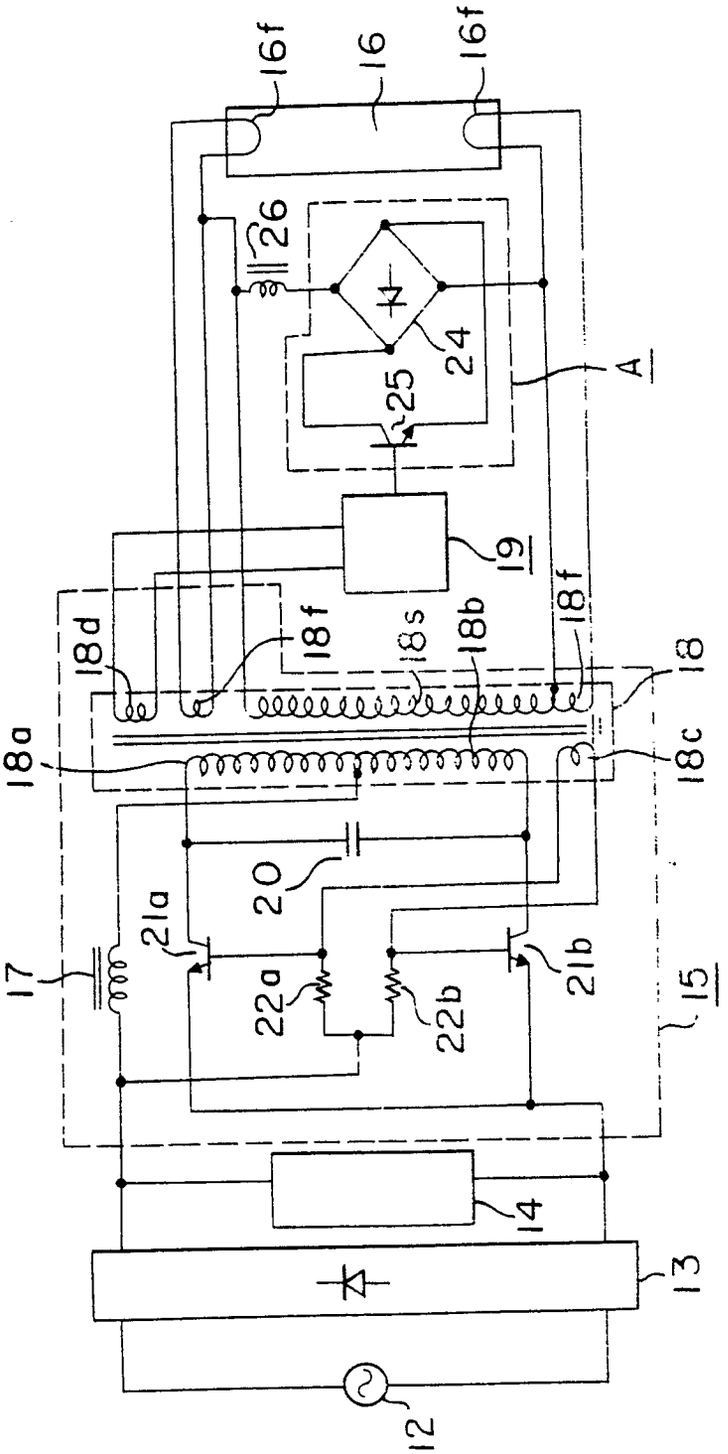

16f
16
16f
26
24
25
A
19
18d
18f
18s
18b
18f
18
18a
18c
20
21a
21b
17
22a
22b
15
14
13
12

FIGURE 28

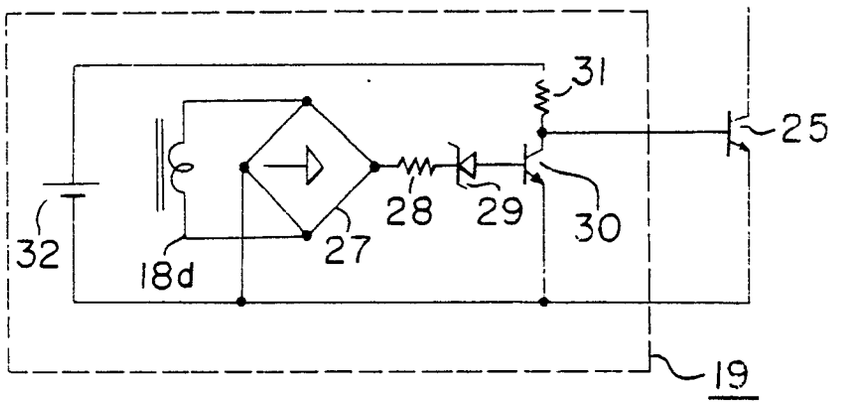


FIGURE 29

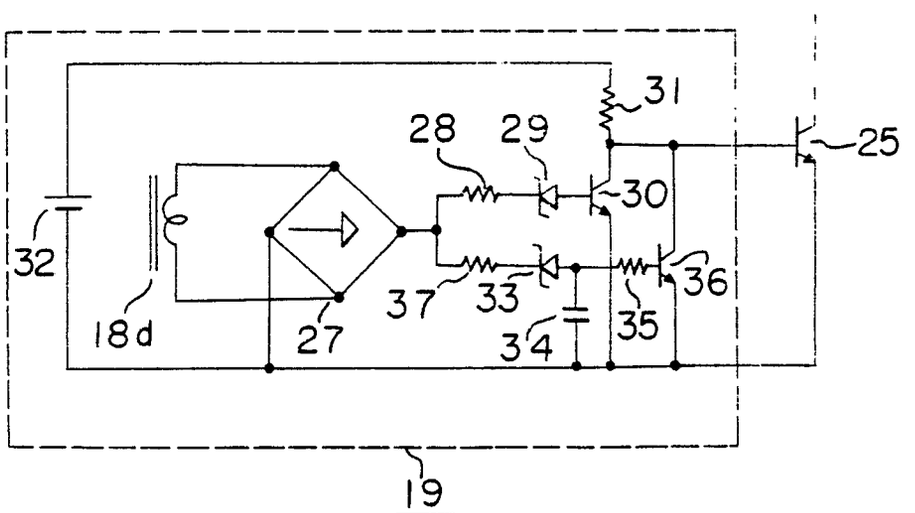


FIGURE 30

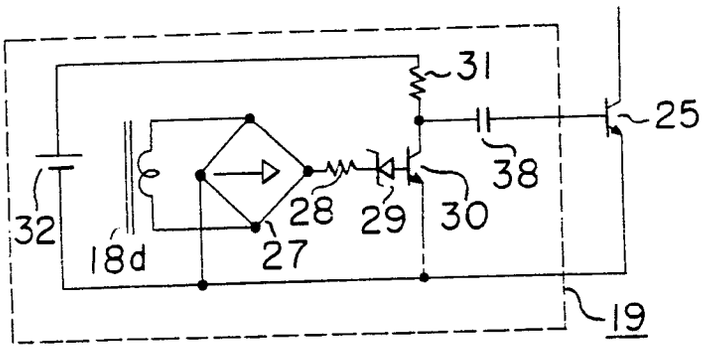


FIGURE 31

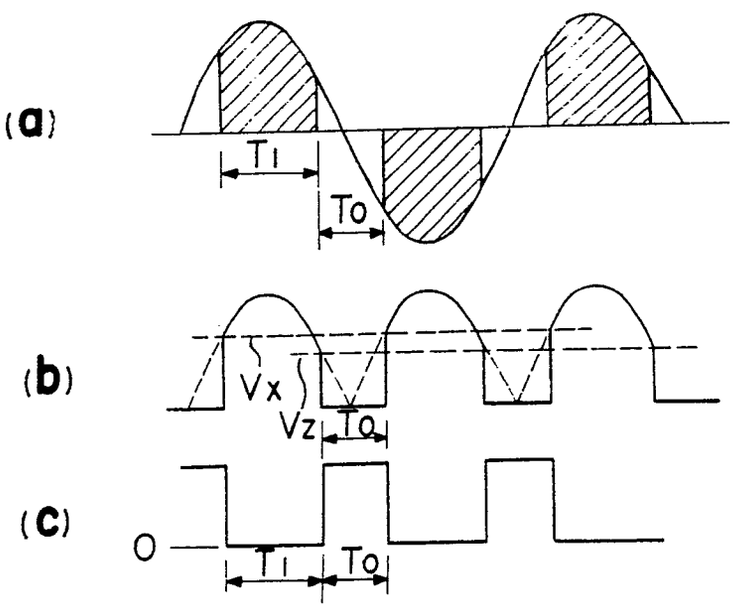


FIGURE 32

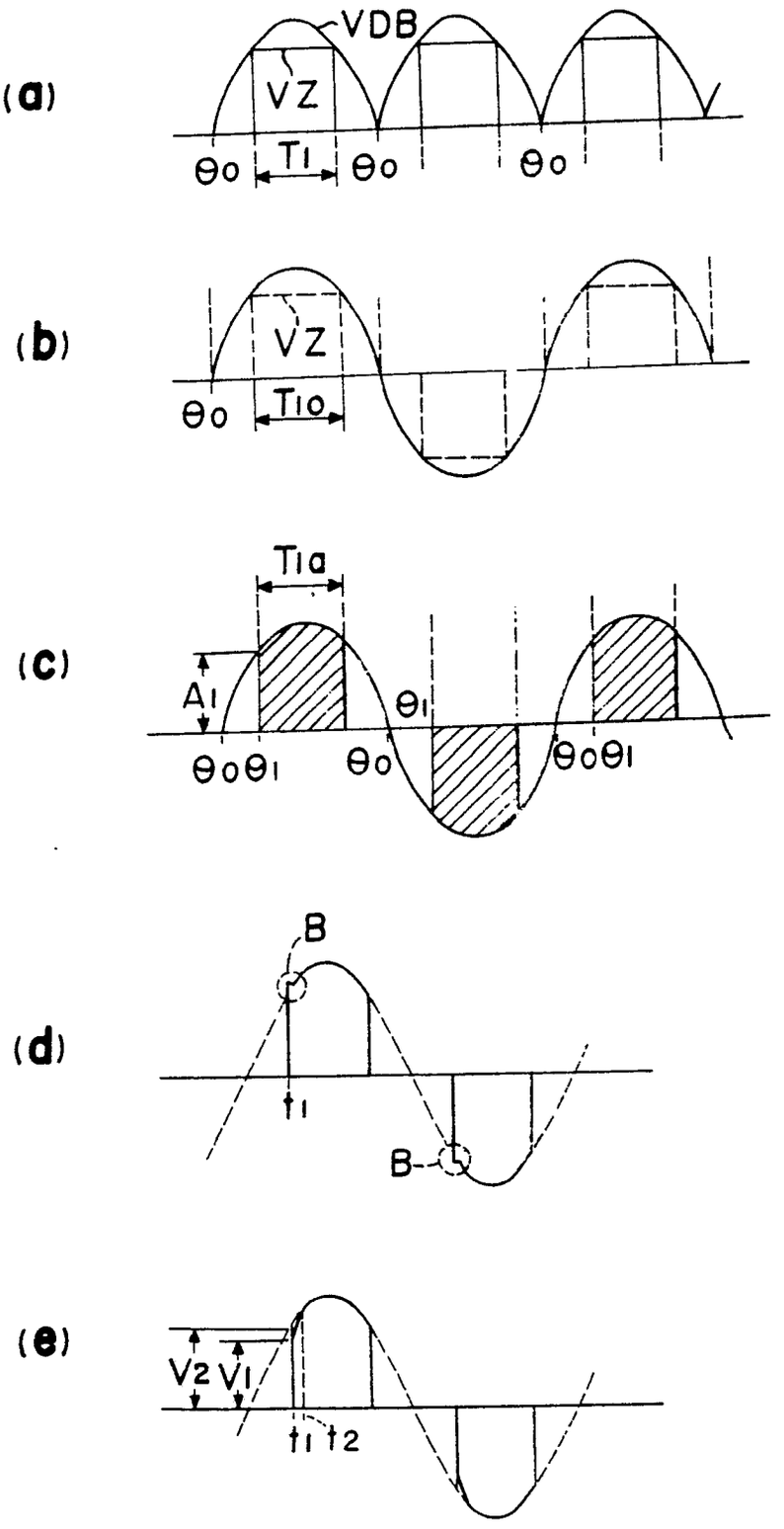

(a)
VDB
VZ
T1
θo
θo
θo
(b)
VZ
T1o
θo
(c)
T1a
A1
θ1
θoθ1
θo
θoθ1
(d)
B
t1
B
(e)
V2
V1
t1
t2

FIGURE 33

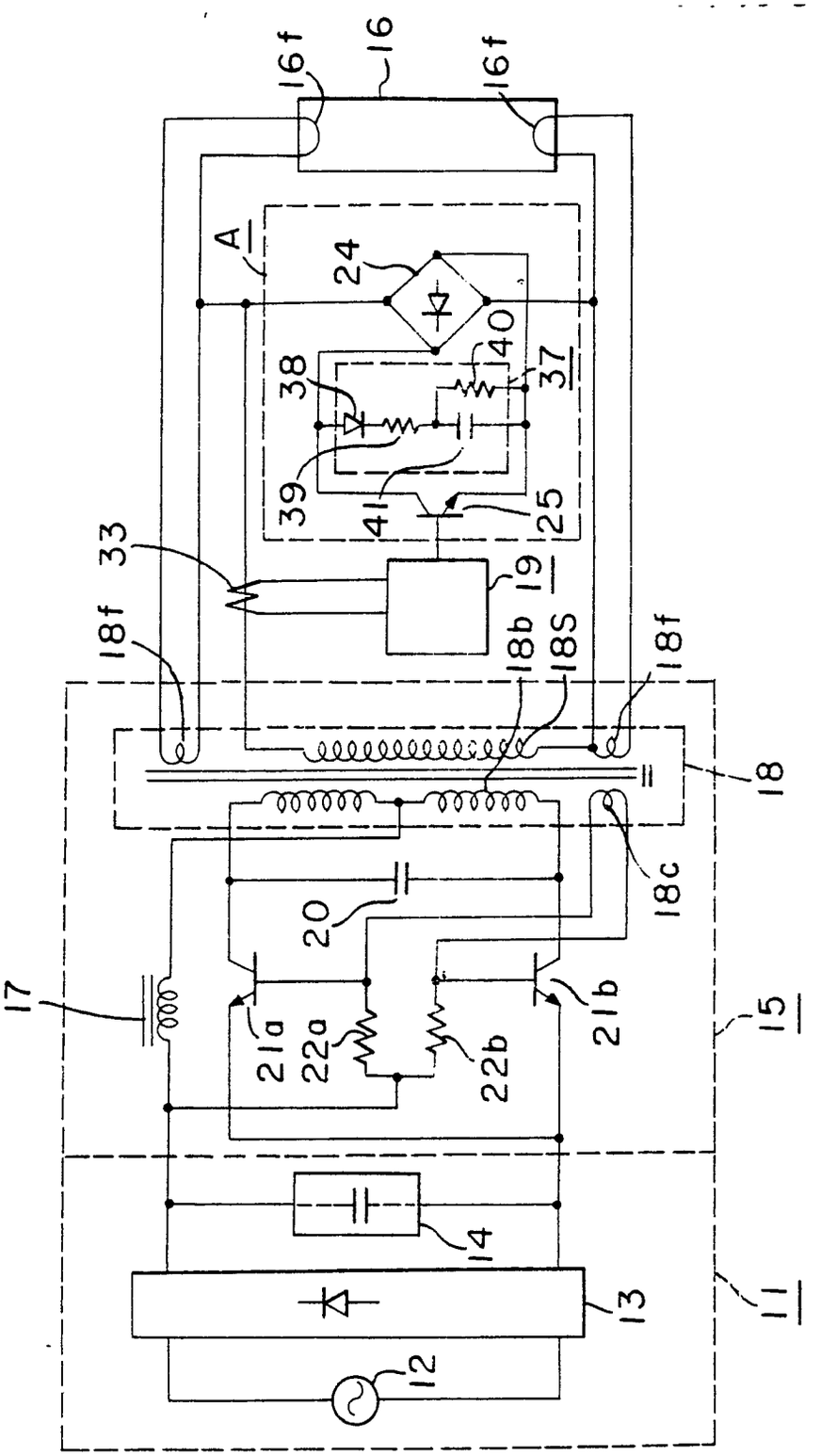

16f
16
16f
A
24
40
37
38
39
41
25
33
19
18f
18b
18S
18f
18
18c
20
17
21a
22a
22b
21b
15
14
13
11
12

FIGURE 34

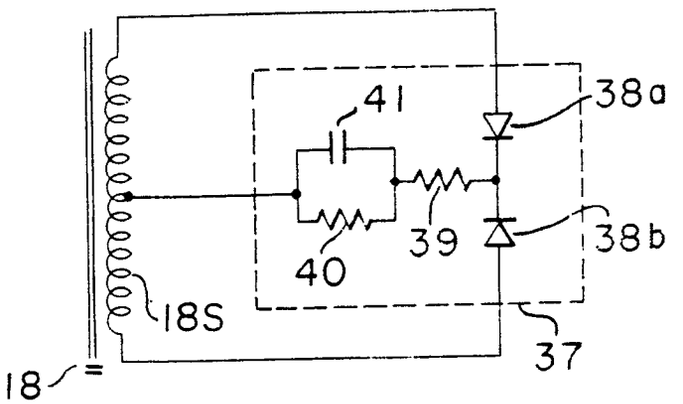


FIGURE 35

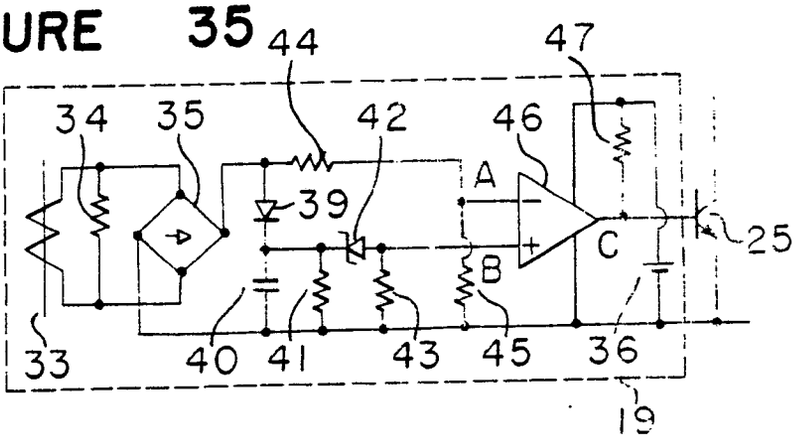


FIGURE 36

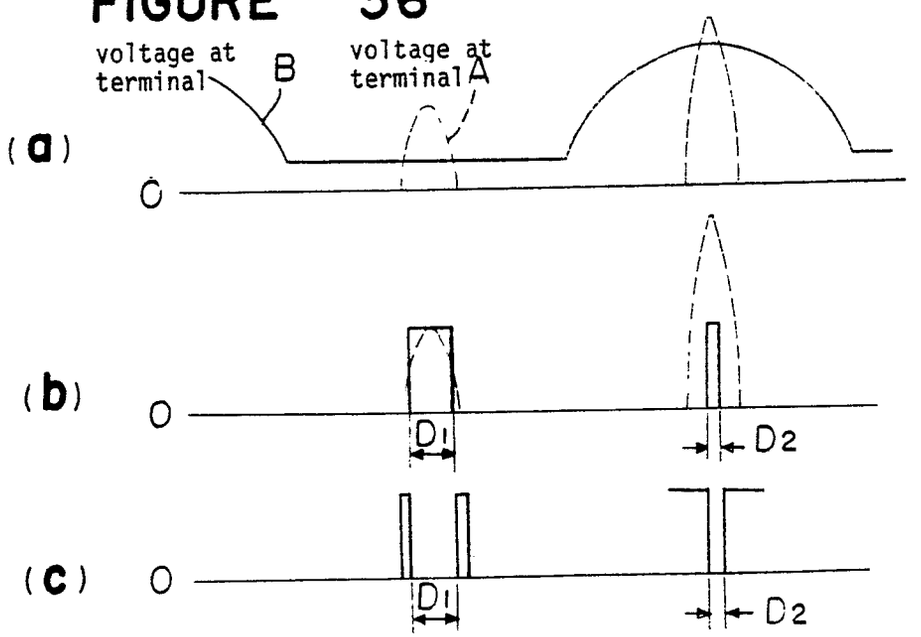


FIGURE 37

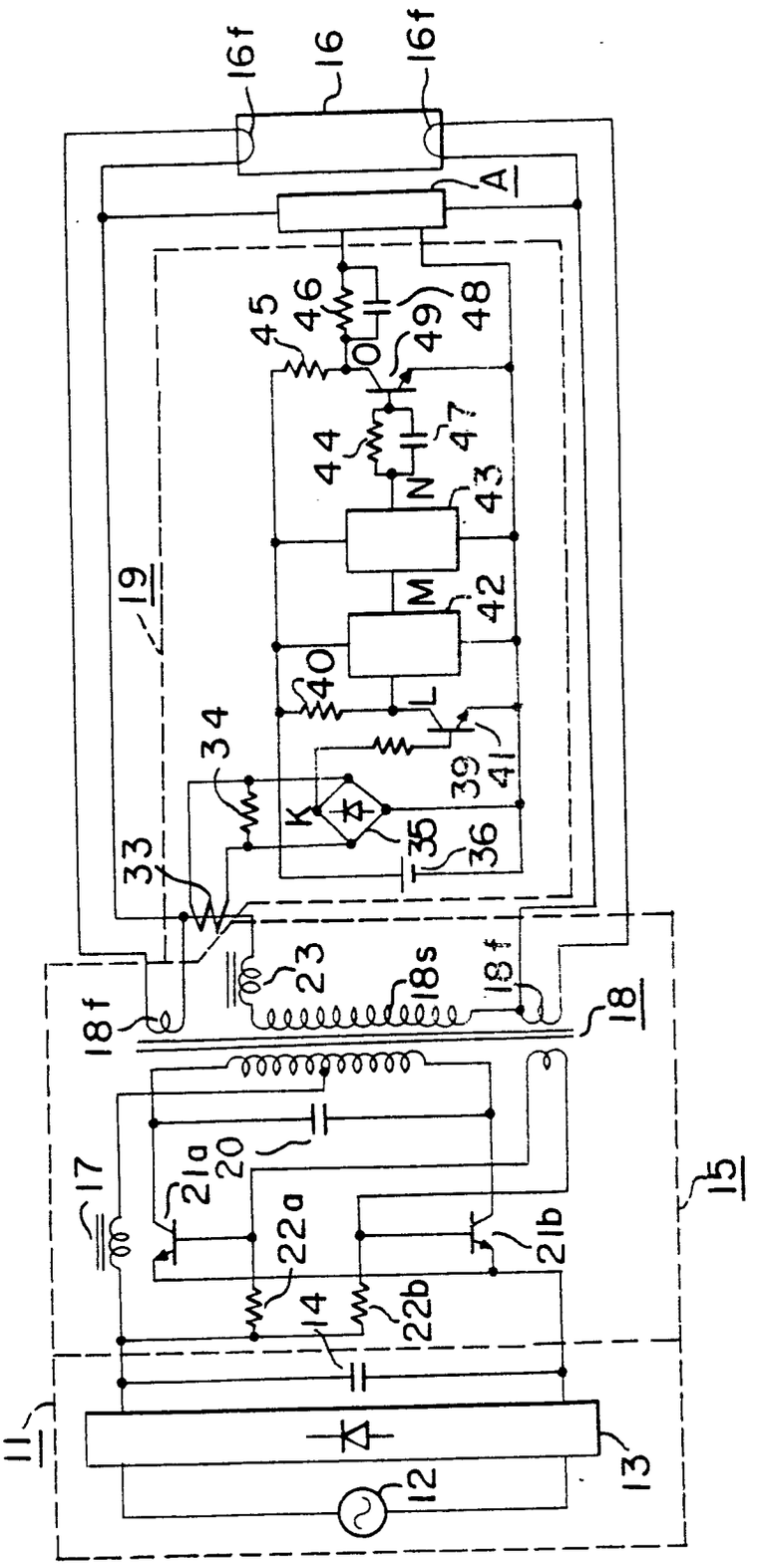

16f
16
16f
A
45
46
49
48
44
47
43
42
40
34
39
41
35
36
33
19
23
18s
18f
18f
18
17
21a
20
22a
21b
15
14
22b
11
13
12

FIGURE 38

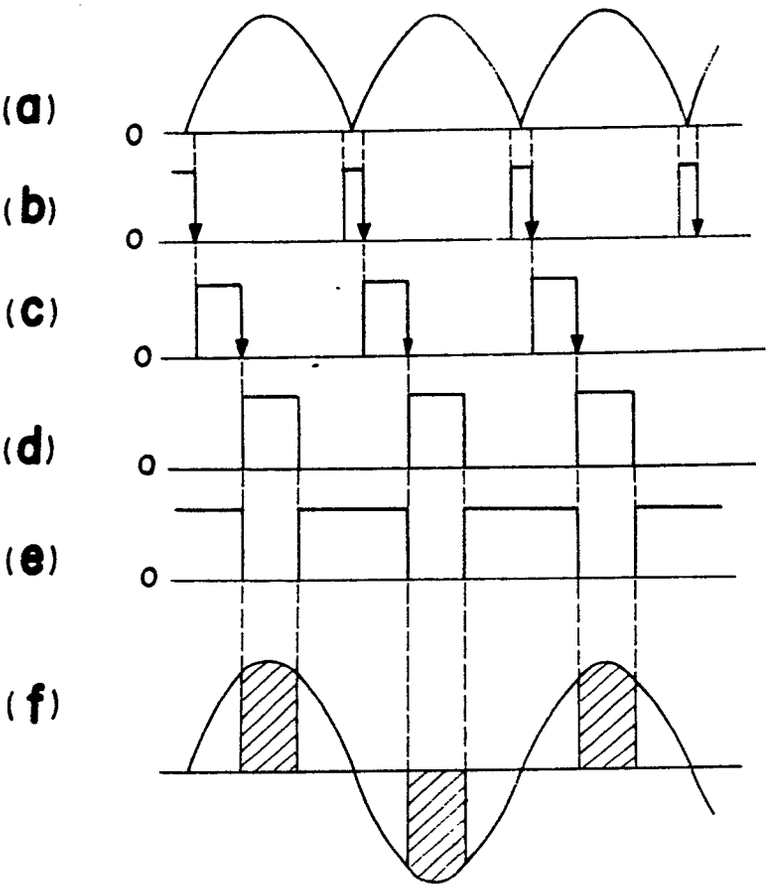


FIGURE 39

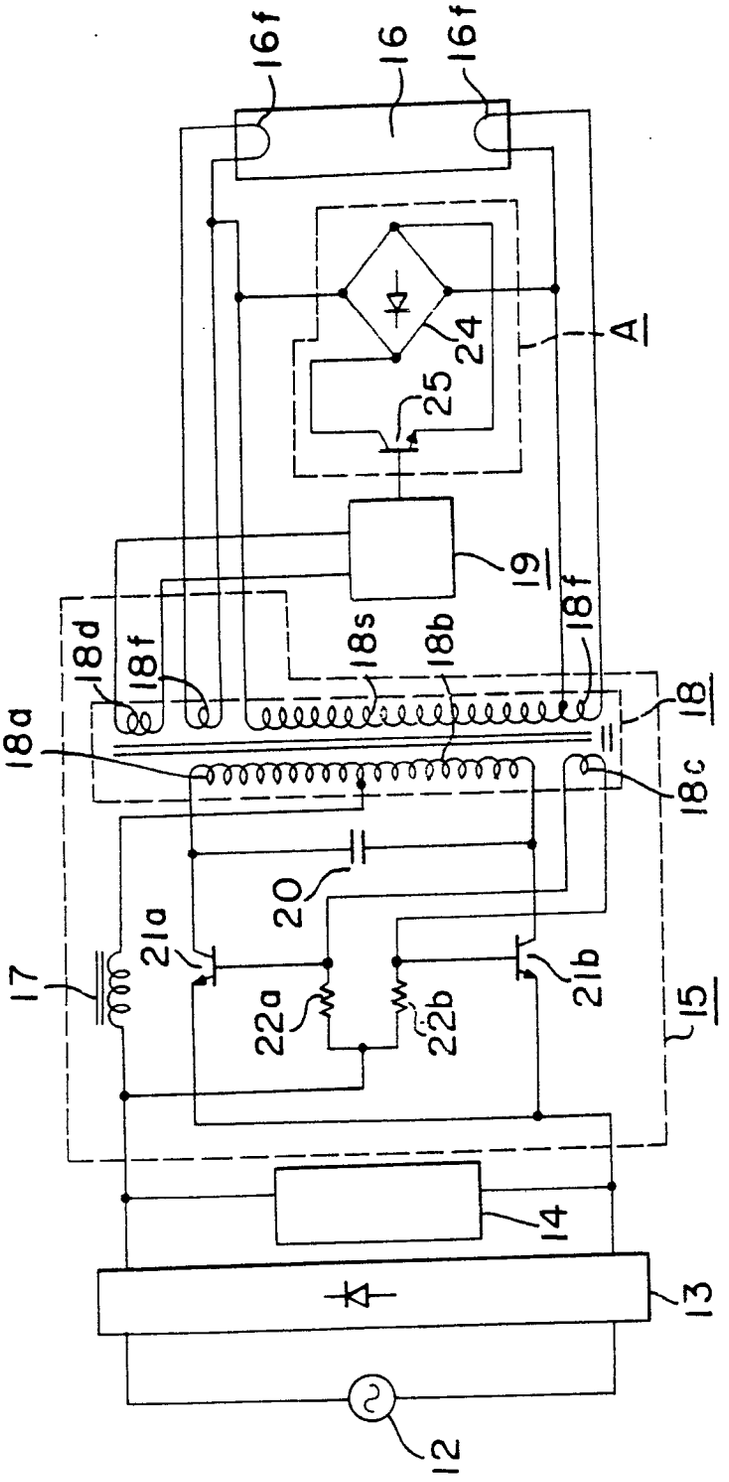

16f
16
16f
A
24
25
19
18f
18s
18b
18d
18f
18a
18
18c
20
21a
21b
17
22a
22b
15
14
13
12

FIGURE 40

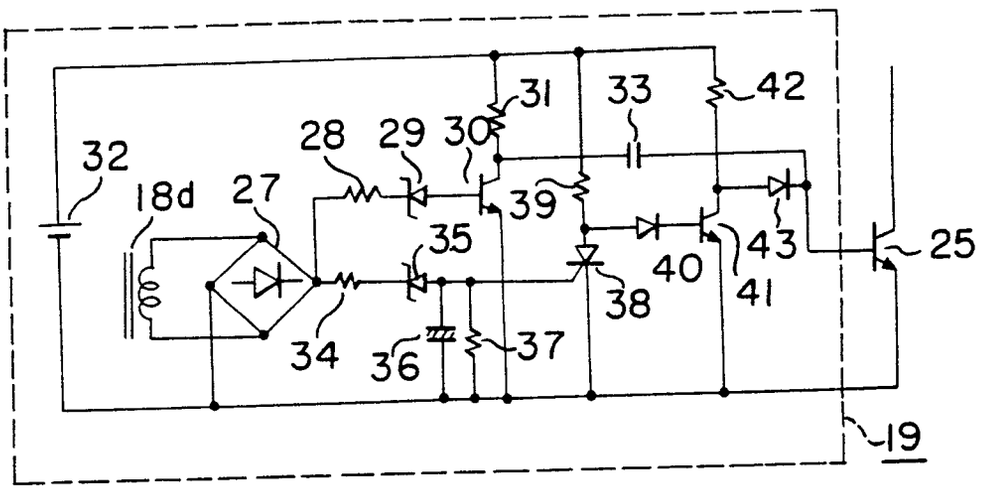


FIGURE 41

