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(54) System for energizing a fluorescent tube.

(57) A fluorescent tube (which may or may not have its heater coils shorted) is energized by a substantially constant current. However, the direction of the substantially constant current is periodically changed. The magnitude of the substantially constant current may be varied by varying the setting of a control member. For example, the movable arm of a potentiometer may be varied. The potentiometer may be included in an optically coupled circuit to give isolated control to the substantially constant current when the position of the movable tap is changed. The movement of the movable arm of the potentiometer causes the duration of the output pulse from a pulse width modulator to vary accordingly. During the production of this output pulse, a switch (e.g. a field effect transistor) is closed so that current is able to flow from a rectified alternating voltage to an energy storage member such as a coil. The coil may be connected to the center tap of an autotransformer to introduce stored energy to the autotransformer during the time that the switch is open. The autotransformer is also connected, at positions displaced from the center tap, to switches which become alternately closed at progressive periods of time to change the direction of the flow of the current through the fluorescent tube.

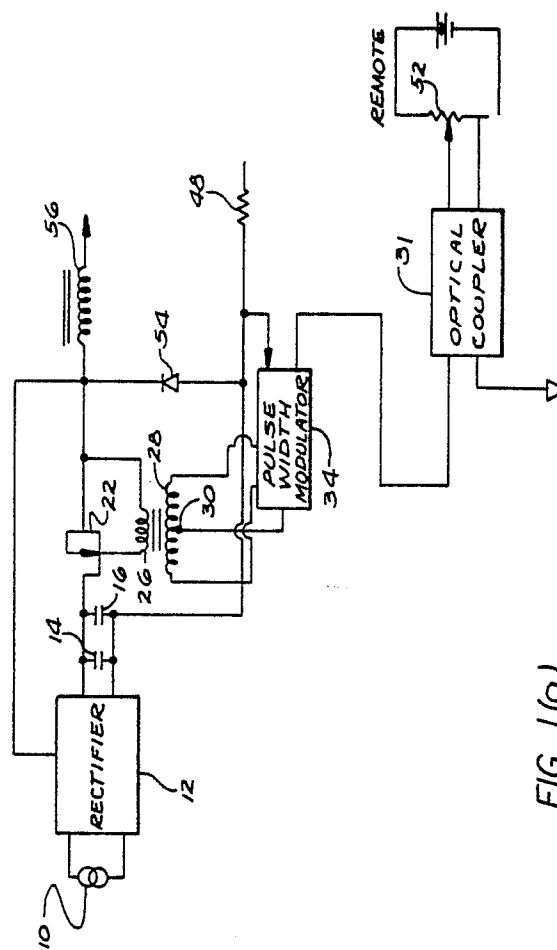


FIG. 1(a)

EP 0 259 603 A1

SYSTEM FOR ENERGIZING A FLUORESCENT TUBE

This is a continuation-in-part of application Serial No. 894,968 filed by me on August 8, 1986, for a "System for Energizing a Fluorescent Tube" and assigned of record to the assignee of record of this application.

This invention relates to a system for energizing a fluorescent tube. More particularly, the invention relates to a system for energizing a fluorescent tube with a substantially constant current at any desired level. The invention is especially adapted to energize the fluorescent tube with the substantially constant current alternately in opposite directions.

Fluorescent tubes have been in existence for decades. During this period, a considerable effort has been devoted, and significant amounts of money have been expended, to perfect such tubes and the systems for energizing the tubes. In spite of such considerable expenditure of effort and money, the systems now in use for energizing the fluorescent tubes are relatively inefficient. The fluorescent tubes also provide a flickering light output and have a relatively limited life. It has also been difficult to provide a controlled amount of light energy in the tubes.

This invention provides a system which overcomes the above difficulties. It provides a minimal power loss in the fluorescent tubes. It provides a substantially constant illumination in the fluorescent tubes with no light flicker. It provides for the flow of current through the tubes at a substantially constant value, which can be precisely controlled even at low values of current. It provides for a long life of the tubes.

In one embodiment of the invention, a fluorescent tube (which may or may not have its heater coils shorted) is energized by a substantially constant current. However, the direction of the substantially constant current is periodically changed. The magnitude of the substantially constant current may be varied by varying the setting of a control member. For example, the movable arm of a potentiometer may be varied. The potentiometer may be included in an optically coupled circuit to give isolated control of the substantially constant current when the position of the movable tap is changed. The movement of the movable arm of the potentiometer causes the duration of the output pulse from a pulse width modulator to vary accordingly.

During the production of the output pulse from the pulse width modulator, a switch (e.g. a field effect transistor) is closed so that current is able to flow from a rectified alternating voltage to an energy storage member such as a coil. The coil may be connected to the center tap of an autotransformer

to introduce stored energy to the autotransformer during the time that the switch is open. The autotransformer is also connected, at positions displaced from the center tap, to switches which become alternatively closed at progressive periods of time to change the direction of the flow of the current through the fluorescent tube.

In the drawings:

Figures 1a and 1b are diagrams, partially in block form, cumulatively indicating a system constituting one embodiment of the invention for producing a flow of a substantially constant current through a fluorescent tube to energize the tube;

Figure 2 is a circuit diagram schematically illustrating additional features of applicant's circuitry for energizing fluorescent tubes in relation to the circuitry for energizing the fluorescent tubes of the prior art;

Figure 3 is a curve illustrating the relationship between voltage and current in circuitry of the prior art for energizing a fluorescent tube and in the circuitry of this invention; and

Figure 4 illustrates waveforms of signals produced at strategic terminals in the circuitry shown in Figures 1a and 1b.

In one embodiment of the invention, a voltage source 10 (Figure 1a) is adapted to provide an alternating voltage from a conventional source such as a wall outlet. The alternating voltage may be in order of 115 volts. The alternating voltage is rectified by a stage 12 and the rectified voltage is introduced to a pair of parallel capacitances 14 and 16 to minimize any ripples in the rectified voltage.

A switch such as that formed by the source and drain of a field effect transistor 22 is connected between the capacitances 14 and 16 and the junction of a diode 54 and a coil 56. A winding 26 is also connected between the gate and the source of the field effect transistor 22. The winding 26 is magnetically coupled as by a ferrite core to a winding 28 having a center tap 30. The number of turns on the winding 28 may be greater than the number of turns in the winding 26.

The center tap 30 of the winding 28 receives the output signals from a pulse width modulator 34. Signals are introduced to the input terminal of the pulse width modulator 34 from an optical coupler 31 and from a sense resistor 48. The output of the optical coupler 31 is controlled by the positioning of a tap in a potentiometer 52 which is energized from a source such as the battery 32 or an external supply source. The optional coupler 31 may be constructed in a manner conventional in the prior art.

The anode of the diode 54 is common with second terminals of the capacitances 14 and 16. The cathode of the diode 54 is also connected to one terminal of a coil 56 (Figures 1a and 1b) having a ferrite core. The second terminal of the coil 56 is common with the center tap of an autotransformer 58 (Figure 1b) having a ferrite core. A fluorescent tube 60 constructed in a conventional manner is connected between the end terminals of the autotransformer 58. The circuit may or may not have windings 57 connected to heater coils 59 in the fluorescent tube 60. The windings 57 may be magnetically coupled to the winding 58.

Terminals 61 and 62 may be provided in the autotransformer 58 intermediate the center tap and the end terminals of the autotransformer. Switches such as those defined by the source and drain of a field effect transistor 64 and the source and drain of a field effect transistor 66 are respectively connected between the intermediate terminals 61 and 62 and a reference potential such as a ground 47. A capacitance 68 and a resistance 70 are in series between the center tap of the autotransformer 58 and the reference potential such as the ground 47.

The gate of the field effect transistor 64 is common with the emitters of a pair of transistors 70 (an NPN) and 72 (a PNP). The collector of the transistor 70 receives a positive voltage from the rectifier 12. The bases of the transistors 70 and 72 are connected to the output terminal of an inverter 74. The collector of the transistor 72 receives the reference potential such as the ground 47.

The output of an amplifier 76 is introduced to the input of the inverter 74. The input terminal of the amplifier 76 is common with one terminal of a capacitance 78, the other terminal of which receives the reference potential such as the ground 47. A resistance 80 is connected between the input terminal of the amplifier 76 and the output terminal of the inverter 74.

The output of the inverter 74 is introduced to an amplifier 82, the output of the amplifier in turn being inverted as at 84. The output of the inverter 84 is introduced to the bases of a transistor 86 (an NPN) and a transistor 88 (a PNP). The collector of the transistor 88 is common with the reference potential such as the ground 47. The emitters of the transistors 86 and 88 are connected to the gate of the field effect transistor 66. The collector of the transistor 86 receives a positive voltage from the rectifier 12.

The alternating voltage from the source 10 is converted into a direct voltage by the rectifier 12 and this direct voltage is smoothed by the capacitances 14 and 16 to minimize ripples. This voltage is introduced to the drain of the field effect transistor 22. When the field effect transistor 22 is conductive, current flows through the transistor, the

coil 56 (Figures 1a and 1b), the autotransformer 58 (Figure 1b), one of the field effect transistors 64 and 66 and the resistance 48 (Figures 1a and 1b). This current is illustrated at 100 in Figure 4. This current causes energy to be stored in the coil 56. The magnitude of the current is dependent upon the output from the optical coupler 31. As previously described, the output from the optical coupler 31 is controlled by an external setting of the movable arm of the potentiometer 52.

Assume now that the position of the movable arm in the potentiometer 52 is changed. This causes the output of the optical coupler 31 to change, thereby changing the output of the pulse width modulator 34 in driving the field effect transistor 22. The change in the output of the pulse width modulator 34 is illustrated in broken lines at 102 in Figure 4. During the production of the signal 102, a voltage is introduced to the field effect transistor 22 to make the transistor conductive.

When the periodic duration for the flow of current through the transistor 22 changes, the amount of energy stored in the coil 56 also changes. During the period of time that the field effect transistor 22 is not conductive, this energy is discharged through a circuit including the coil 56, the autotransformer 58, one of the field effect transistors 64 and 66, the resistance 48 (Figures 1a and 1b) and the diode 54 (Figures 1a and 1b). Thus, the change in the magnitude of the energy in the coil 56 will cause a corresponding change to be produced in the voltage in the resistance 48.

The circuitry discussed above acts, as a practical matter, as a servo system. When a change is provided in the positioning of the movable arm of the potentiometer 52, a corresponding change is produced in the average value of the current in the resistance 48. In this way, the duration of the periodic pulses 100 from the pulse modulator 34 is adjusted (as indicated at 102) to a level representative of the positioning of the movable arm in the potentiometer 52. This causes the current flowing through the autotransformer 58 to become adjusted to a value representative of the positioning of the movable arm of the potentiometer 52.

The direction of the flow of the substantially constant current through the autotransformer 58 is controlled by the circuitry shown in Figure 1b. This circuitry includes the amplifier 76, the inverter 74, the resistance 80 and the capacitance 78. This circuitry acts as a Schmidt trigger in a conventional manner to produce alternatively positive and negative pulses at the output from the inverter 74. The alternately positive and negative pulses are produced by alternatively charging the capacitance 78 to a level for making the amplifier 76 conductive and then discharging the capacitance through the amplifier. The positive pulses from the inverter 74

pass through the transistors 72 and 70, which provide substantially a 1:1 gain in the signals from the inverter and isolate the amplifier 76 and the inverter 74 from the field effect transistor 64. These pulses cause the transistor 64 to become conductive.

When the transistor 64 becomes conductive, a current flows through a circuit including the autotransformer 58, the transistor, the resistance 70 and the capacitance 68. This current is produced because of the voltage across the coil 56. This current produces a voltage between the center tap and the intermediate terminal 61 of the autotransformer 58. This voltage is stepped-up across the autotransformer and this stepped-up voltage is applied to the fluorescent tube 60 to produce a flow of current toward the left in Figure 1b. This current is substantially constant and is reduced relative to the current flowing through the transistor 64 because of the stepped-up voltage produced across the autotransformer 58.

During the time that the inverter 74 produces a low voltage, the inverter 84 produces a high voltage. This voltage is applied through the isolating transistors 88 and 86 (which perform the same functions as the transistors 72 and 70) to the transistor 66 to make the transistor 66 conductive. Current then flows through a circuit including the autotransformer 58 between the center tap and the intermediate terminal 62 of the autotransformer 58, the transistor 66, the resistance 70 and the capacitance 68. This current is in an opposite direction to that produced in the autotransformer 58 when the transistor 64 is conductive. This current produces in the autotransformer 58 a stepped-up voltage which causes a substantially constant current to flow through the fluorescent tube 60. This current is in a direction opposite to the direction of the current in the fluorescent tube when the transistor 64 is conductive.

The invention described above has certain important advantages. It provides for a flow through the fluorescent tube of a substantially constant current which can be precisely controlled. Since the current is substantially constant, the fluorescent tube produces light without any flicker. Although the current through the fluorescent tube is substantially constant, the direction of the current through the tube is periodically alternated. This enhances the life of the tube considerably.

The power losses in the fluorescent tube 60 included in the system of this invention are relatively low. This results from the fact that the fluorescent tube 60 is energized at a substantially constant level even when the direction of the current flow through the tube is changed periodically. This assures that ions are constantly excited in the tube. The power losses in the fluorescent tube are relatively low for another reason. This results from

the fact that the heater coils 59 at the opposite ends of the tube may be shorted electrically. This is illustrated in Figure 2. This is in contrast to the prior art which passes current through the heater coils 59 to heat the coils. As will be appreciated, such heater current results in a considerable power loss.

Figure 3 illustrates the relationship between the voltage and current in the fluorescent tubes of the prior art. As will be seen at 112 in Figure 3, a voltage as high as one thousand volts (1000v) has to be introduced across the fluorescent tube to excite the tube. When the tubes have been energized, a voltage of the order of one hundred and twenty volts (120v) may be sufficient to maintain the tube energized and to produce progressive amounts of current in the tube.

In the prior art, the current varies from "zero" to several hundred milliamperes at a rate of 120 times per second, once each peak in the positive and negative cycles of the 60 Hertz wave. As a result, the fluorescent tube becomes de-energized in each half cycle of the energizing voltage and has to be re-energized in each such half cycle. This requires that a voltage of approximately one thousand (1000v) volts is applied to the tube in each half cycle of the alternating voltage. This voltage is obtained from the ballast in the tube. It causes pulsating currents to be produced in the fluorescent tubes of the prior art, as indicated at 120, when a sine wave signal 122 is introduced to the tubes. Such de-energization and re-energization of the tube in each half cycle of the alternating voltage may result in a low efficiency in the tube and provide for a limited life of the tube.

In contrast, the system of this invention is able to operate the fluorescent tube with a substantially constant current with an energy source that will provide the proper voltage for that current setting. This may be seen at 114 in Figure 3. As in the systems of the prior art, this voltage remains substantially constant with progressive amplitudes of the current through the tube after the gas in the tube has been ionized initially with a high voltage. Once the fluorescent tube 60 is energized, it remains energized throughout the successive half cycles of the input alternating voltage. This occurs in part because the input alternating voltage is converted to a direct voltage and because the coil 56 stores energy for introduction to the fluorescent tube 60 during the period of time that the transistor 22 is not energized. Since the fluorescent tube 60 in the system of this invention remains constantly energized and since the magnitude of the current through the tube remains substantially constant throughout the successive half cycles of the al-

ternating voltage, the fluorescent tube 60 in the system of the invention operates at an optimal efficiency. This insures that the fluorescent tube 60 will have a long life.

Although this invention has been disclosed and illustrated with reference to particular embodiments, the principles involved are susceptible for use in numerous other embodiments which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

Claims

1. In combination for exciting a fluorescent tube to obtain luminescence from the tube, means for providing a direct voltage, control means having a variable setting, switching means, energy storage means, means connected in a circuit with the direct voltage means, the switching means and the energy storage means and responsive to the setting of the variable control means for obtaining a controlled flow of current from the direct voltage means through the switching means to the energy storage means for a period of time dependent upon the setting of the variable control means to obtain a controlled storage of energy in the energy storage means, and means operatively coupled to the fluorescent tube for obtaining the release of the energy stored in the energy storage means alternately through the fluorescent tube in opposite directions to energize the tube.

2. In a combination as set forth in claim 1, an autotransformer having a center tap and first and second terminals displaced along the autotransformer in opposite polarities from the center tap, the circuit-connecting means being coupled to the first and second terminals of the autotransformer, and the energy storage means being connected to the center tap of the autotransformer.

3. In a combination as set forth in claim 1, a pulse width modulator responsive to variations in the setting of the control means for adjusting the period of time that the current flows from the direct voltage means through the switching means to the energy storage means.

4. In a combination as set forth in claim 1, the energy-release means including means connected to the energy storage means for stepping up the voltage, and stepping down the current, introduced to the fluorescent tube from the energy

storage means and for facilitating the flow of the current through the fluorescent tube alternately in opposite directions.

5. In combination for exciting a fluorescent tube to obtain luminescence from the tube, control means having a variable setting, energy storage means, first means responsive to the variable setting of the control means for providing a variable storage of energy in the energy storage means in accordance with such variable setting, second means connected to the fluorescent tube and to the energy storage means for energizing the fluorescent tube in accordance with the energy in the energy storage means, and third means connected to the second means for obtaining the energizing of the fluorescent tube alternately in opposite directions.

6. In a combination as recited in claim 5, the fluorescent tube having first and second output terminals, the third means including bistable means having first and second output lines, the bistable means alternately providing outputs on the first and second output lines, the first and second output lines being respectively coupled electrically to the first and second opposite terminals of the fluorescent tube.

7. In a combination as set forth in claim 5, the second means including an autotransformer having a center tap and taps removed in the autotransformer from the center tap, the removed taps of the autotransformer being connected to the fluorescent tube, the center tap of the autotransformer being connected to the first means.

8. In a combination as set forth in claim 5, the first means including a pulse width modulator responsive to variations in the setting of the control means for producing a pulse having a variable width and also including means for producing a variable current through the energy storage means in accordance with the variations in the pulse width to obtain resultant variations in the energy stored in the energy storage means.

9. In combination, a fluorescent tube, means for providing a direct voltage, control means having a variable setting, first means responsive to the variable setting of the control means for providing a level of energy dependent upon such variable setting, second means responsive to the energy from the first means for energizing the fluorescent tube at a substantially constant value dependent upon the level of such energy from the first means, and third means operatively coupled to the second

means for obtaining an energizing of the fluorescent tube at the constant levels alternately in opposite directions.

10. In a combination as recited in claim 9, the first means including a switch responsive to the variable setting of the control means for becoming closed at a relative percentage of time dependent upon such variable setting and further including an energy storage member for cumulatively storing energy during the period of time that such switch is closed.

11. In a combination as set forth in claim 10, the third means including bistable means having first and second states of operation, the bistable means being operatively coupled to the fluorescent tube to activate the fluorescent tube in a first direction in the first state of operation of the bistable means and to activate the fluorescent tube in a second direction opposite to the first direction in the second state of operation of the fluorescent tube.

12. In a combination as set forth in claim 9, the fluorescent tube having heater elements, the heater elements being shorted, the third means including bistable means having first and second states of operation, the bistable means being operatively coupled to opposite ends of the fluorescent tube to activate one end of the fluorescent tube in the first state of operation of the bistable means and to activate the other end of the fluorescent tube in the second state of operation of the bistable means.

13. In combination as set forth in claim 9, the fluorescent tube having heater elements, and means for energizing the heater elements.

14. In combination, a fluorescent tube having heater elements at opposite ends of the tube, means for shorting the heater elements, means for producing a substantially constant current through the fluorescent tube, and means for periodically changing the direction of the flow of the substantially constant current through the fluorescent tube.

15. In combination, a fluorescent tube having heater elements at opposite ends of the tube, means for heating the heater elements, means for producing a substantially constant current through the fluorescent tube, and means for periodically changing the direction of the flow of the substantially constant current through the fluorescent tube.

16. In a combination as recited in claim 14, control means having a variable setting, and means responsive to variations in the setting of the control means for changing the magnitude of the substantially constant current in the fluorescent

tube in the opposite directions in accordance with such variations in such setting of the control means.

17. In a combination as set forth in claim 15, control means having a variable setting, and means responsive to variations in the setting of the control means for changing the magnitude of the substantially constant current in the fluorescent tube in the opposite directions in accordance with such variations in such setting of the control means.

18. In a combination as set forth in claim 14, the direction-changing means including bistable means alternately operable in first and second states of operation and connected to the fluorescent tube to activate the fluorescent tube in a first direction in the first state of operation of the bistable means and to activate the fluorescent tube in a second direction opposite to the first direction in the second state of operation of the bistable means.

19. In a combination as recited in claim 17, control means having a variable setting, means responsive to variations in the setting of the control means for changing the magnitude of the substantially constant current in the fluorescent tube in accordance with such variations in such setting of the control means, and an autotransformer having a center tap and having terminals removed in opposite polarities from the center tap and connected to the fluorescent tube, the constant current means being connected to the center tap of the autotransformer and the bistable means being connected to the removed terminals of the autotransformer.

20. In a combination as set forth in claim 15, the direction-changing means including bistable means alternately operable in first and second states of operation and connected to the fluorescent tube to activate the fluorescent tube in a first direction in the first state of operation of the bistable means and to activate the fluorescent tube in a second direction opposite to the first direction in the second state of operation of the bistable means.

21. In a combination as set forth in claim 20, control means having a variable setting, means responsive to variations in the setting of the control means for changing the magnitude of the substantially constant current in the fluorescent tube in accordance with such variations in such setting of the control means, and an autotransformer having a center tap and having terminals removed in opposite polarities from the center tap and connected to the fluorescent tube, the constant current means being connected to the

center tap of the autotransformer and the bistable means being connected to the removed terminals of the autotransformer.

22. In combination,
a fluorescent tube, 5
control means having a variable setting,
means operatively coupled to the fluorescent tube
and responsive to the setting of the control means
for energizing the fluorescent tube at a substan- 10
tially constant energy level dependent upon the
setting of the control means, and
means operatively coupled to the fluorescent tube
for periodically obtaining an energizing of the flu-
orescent tube at the substantially constant level in
first and second opposite directions. 15

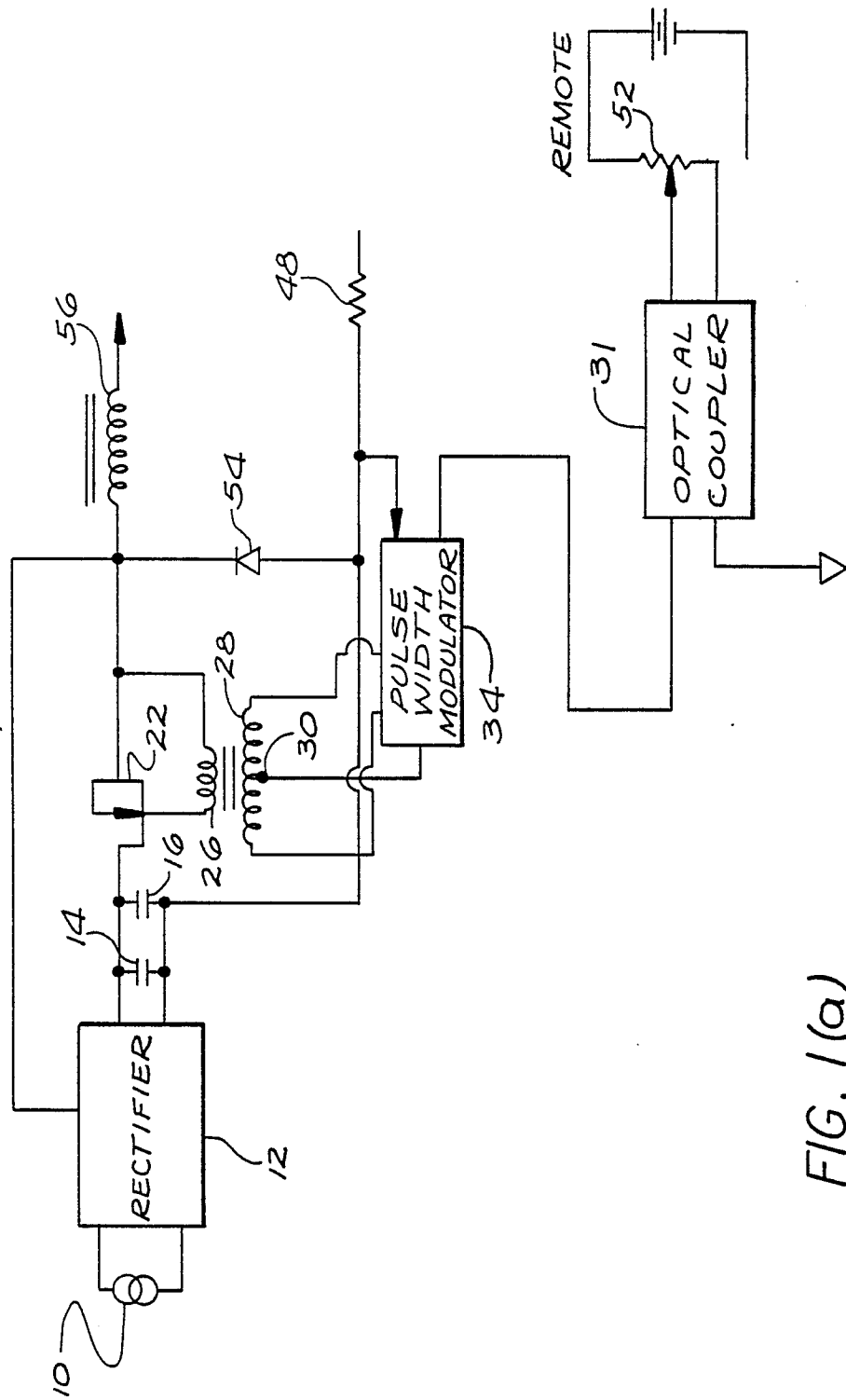
23. In a combination as set forth in claim 22,
an autotransformer having a center tap and termi-
nals removed in opposite polarities from the center
tap,
the autotransformer terminals removed from the 20
center tap being connected to the directional en-
ergizing means and to the fluorescent tube and the
center tap of the autotransformer being connected
to the means for energizing the fluorescent tube at
the substantially constant level. 25

24. In a combination as set forth in claim 20, a
switch,
means for periodically producing a flow of current
through the switch for a percentage of time depen- 30
dent upon the setting of the control means, and
means responsive to the current through the switch
for storing a substantially constant energy at a level
dependent upon the percentage of time for such
periodic flow of current.

25. In a combination as set forth in claim 24, 35
the energy storage means being operatively coup-
led to the fluorescent tube to introduce energy to
the fluorescent tube for energizing the fluorescent
tube at the substantially constant level, and
means responsive to the direct voltage and to the 40
setting of the control means for producing a flow of
current through the switch to the energy storage
means at a duty cycle dependent upon the setting
of the control means. 45

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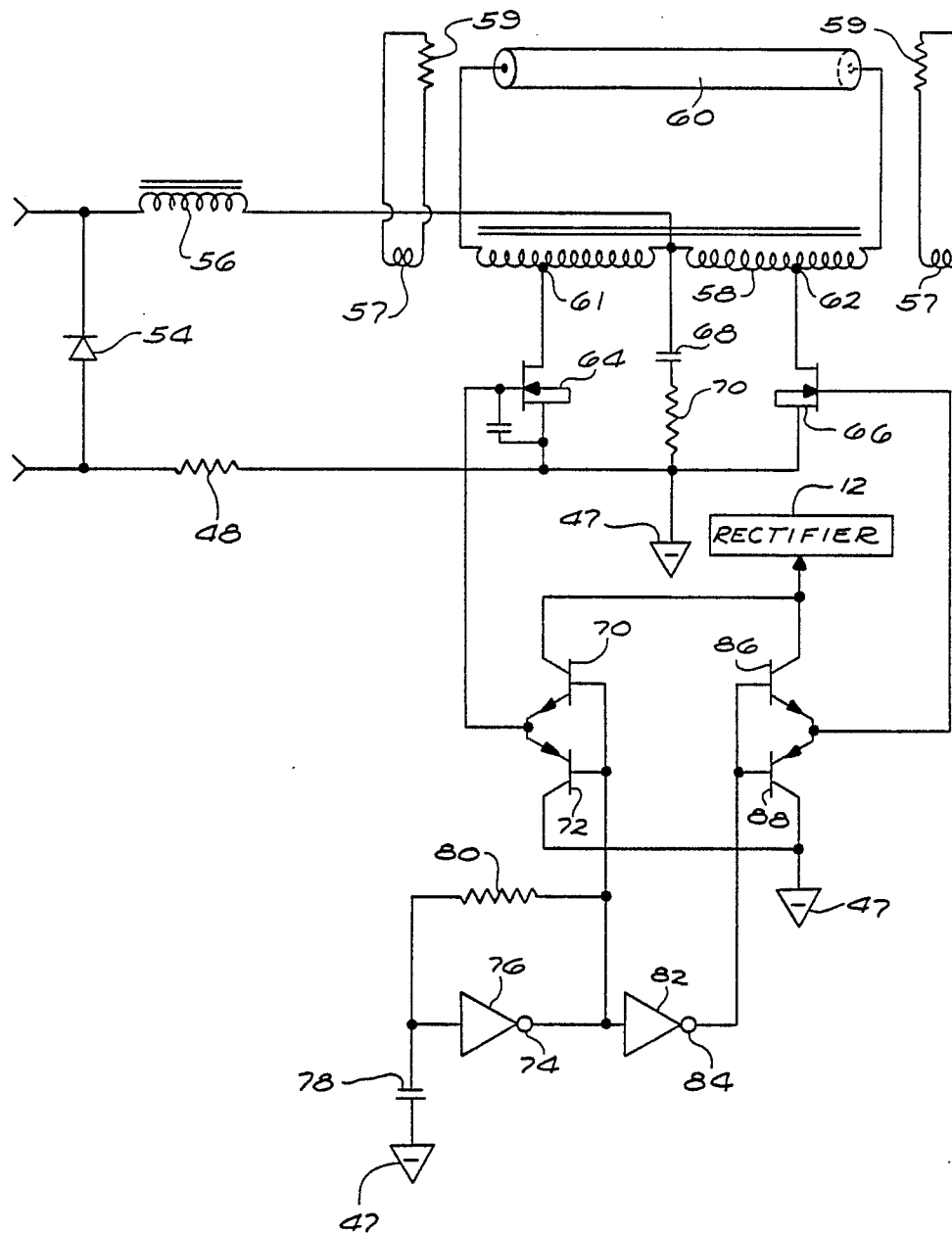


FIG. 1(b)

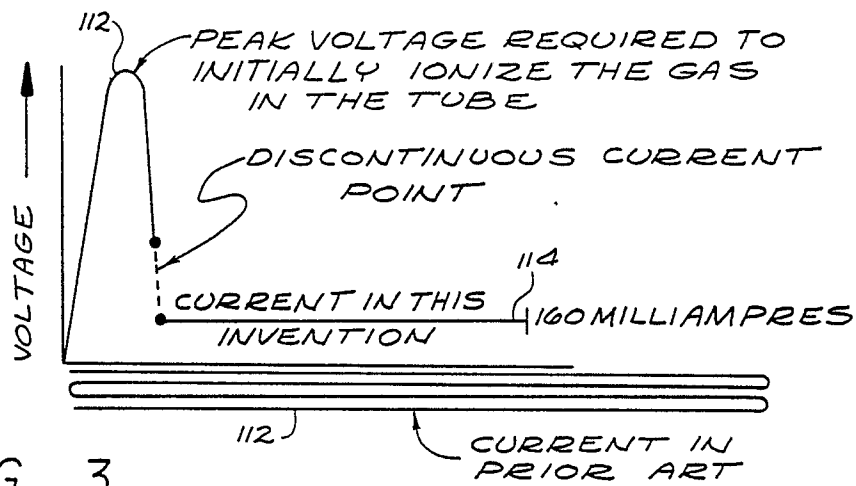
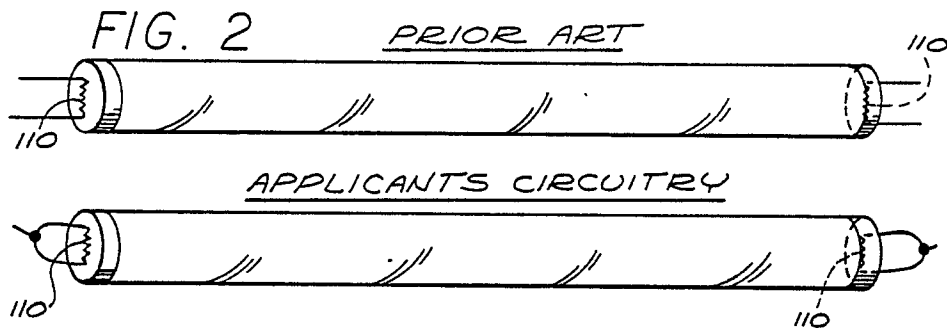


FIG. 3

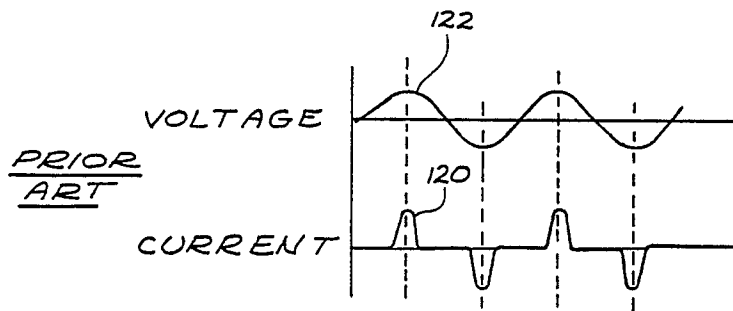
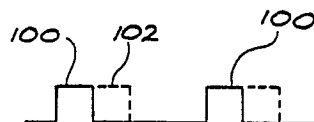


FIG. 4





EP 87 11 1263

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
X	US-A-4 373 146 (BONAZOLI) * Column 3, line 6 - column 4, line 16; figure 1 * ---	1-10	H 05 B 41/29
A	FR-A-2 489 069 (USHIO DENKI) * Page 3, line 29 - page 6, line 4; figure 1 * -----	1-10	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
			H 05 B 41/00
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 29-12-1987	Examiner DUCHEYNE R.C.L.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			