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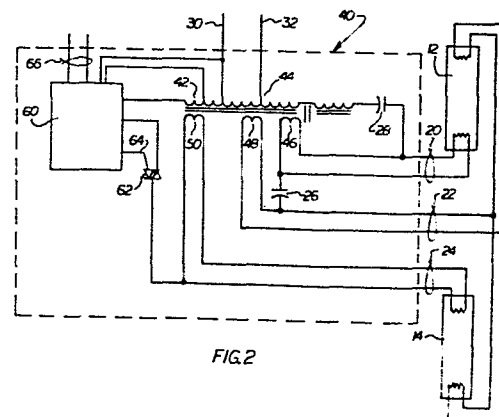
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54 **Circuit and method for controlling the output illumination of one or more gas discharge lamps.**

57 An integral ballast and control circuit (40) provides control of the output illumination through a timed interval controlled impedance (62), serially coupled between a winding of a magnetic ballast and series connected gas discharge lamps (12,14). When in its non-conducting state, the controlled impedance 62 interrupts the lamp discharge current. A timed control signal is applied to the impedance 62 at a gate electrode 62 by a control circuit 60 which receives power and timing signals from the magnetic ballast. The illumination level adjacent the lamps (12,14) is sensed by photocell (72) connected by leads (66) to the control circuit (60), which includes two control loops, one responding to the photocell output and the other to the lamp discharge current sensed adjacent the controlled impedance (62).



CIRCUIT AND METHOD FOR CONTROLLING THE
OUTPUT ILLUMINATION OF ONE OR MORE GAS DISCHARGE LAMPS

This invention relates to circuitry for controlling the output illumination level of gas discharge lamps and, more particularly, to circuitry having load side control using a controlling impedance coupled between a

5 transformer primary winding and the gas discharge lamps.

Numerous techniques have been proposed for controlling the output illumination level of gas discharge lamps. One example of a system providing lamp dimming in response to selected illumination levels is illustrated in
10 U.S. Patent No. 4,197,485. Deficiencies, however, impeding development of this technology include reduced net efficiency (lumen output per wattage input) of the lighting system as well as costly and burdensome dimming circuitry when sophistication is sufficient to provide
15 efficient dimming.

An alternative commonly employed to increase overall efficiency in dimming systems is to convert line frequency to higher frequencies. U.S. Patents Nos. 4,207,497 and 4,207,498 are illustrative of this technique.

20 It is an object of the present invention to provide efficient and effective dimming or controlling of the lighting output of fluorescent lighting fixtures or other gaseous discharge lamps whereas previous dimming and lighting control resulted in ineffective dimming
25 particularly where multiple lighting fixtures were encountered.

European patent applications Nos. 82 303452.5 and 82 305283.2 are concerned with control circuits functioning with a standard magnetic ballast to control
30 the output illumination level of gas discharge lamps. The control circuitry of these noted applications are intended for use in previously designed lighting units, either before market or after market, wherein the standard

magnetic ballast is utilized in a two-lamp or four-lamp lighting system, respectively. In order to be capable of accurately and efficiently operating with a multitude of magnetic ballasts which might be encountered, the control
5 circuits include a circulating inductor coupled in parallel with a controlled impedance such that current is provided to the lamps during a portion of the AC signal when the controlled impedance would be nonconductive due to the operation of the control circuitry.

10 It should be noted that European patent applications Nos. 82 303452.5 and 82 305283.2 provide detailed descriptions of operations of modular lighting control systems similar to that of the present invention. While the two European patent applications noted above concern a
15 modular control lighting arrangement to be used in conjunction with a standard magnetic ballast, the present invention is concerned with an integral control circuit and magnetic ballast to be used instead of a standard magnetic ballast as opposed to in conjunction therewith.

20 The present invention concerns an apparatus and method of controlling the output illumination level of gas discharge lamps such as flurorescent lighting systems, and is directed at a simple, yet efficient, method for illumination control of gas discharge lamps operating at
25 line frequency. Excellent power factor is maintained while providing illumination control from 10 to 1 dimming, and excellent current crest factor in addition to reduced lamp current and reduced ballast losses are obtained. Control of illumination is provided by a timed interval
30 controlled impedance, serially coupled between the primary winding of a magnetic ballast and the lamps. A current path for cathode heating current is maintained between the power source and the lamps during the portion of the AC signal in which the controlled impedance is in a
35 substantially nonconductive state. This arrangement provides for substantially no reduction in the cathode

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heating voltage supplied to the lamps while the circuitry is connected to a power source. Illumination control is possible in the range of 10% to 100% of full intensity illumination as a result of the apparatus and method of the present invention.

As noted above, a circulating inductor was found to be necessary in order to adequately and efficiently control illumination of a lighting system when a standard magnetic ballast of one of a number of manufacturers was encountered. The present invention contemplates a unit including both the magnetic ballast components as well as the illumination control components. Specifically, an integral ballast and control circuit arrangement is provided for original manufacture or retrofitting of the entire ballast of existing lighting structures. As a result, the circulating inductor can be eliminated. More importantly, additional magnetics may be eliminated as part of the illumination control circuitry since a single magnetic ballast arrangement can be utilized for both functions. Additionally, no limitations are imposed upon the connection of the illumination control circuitry to the magnetics as in the case of a standard magnetic ballast. The ability to connect appropriate circuitry for illumination control at any point internal to the magnetics provides additional efficiency of the present unit.

The present invention is defined in the claims hereinafter. The invention will now be described in more detail, solely by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 illustrates a conventional magnetic ballast, two-lamp fluorescent lighting system;

Fig. 2 illustrates one embodiment of the illumination control system of the present invention;

Fig. 3 illustrates another embodiment of the illumination control system of the present invention;

Fig. 4 illustrates, in block diagram format, a control circuit of the present invention; and

Fig. 5 illustrates a specific embodiment of the invention.

5 In the drawings, Fig. 1 illustrates a conventional fluorescent lighting installation serving as a basis for discussing the novel characteristics of the present invention. A standard magnetic ballast 10, which is essentially a complex transformer wound on an iron core, 10 drives two serially connected gas discharge (fluorescent type) lamps 12 and 14. As used in Fig. 1, the ballast 10 includes three lead pairs 20, 22 and 24, each of which is driven from a winding in the ballast 10. The ballast also includes a starting capacitor 26 and a series capacitor 15 28, the last of which serves to correct for power factor. In operation, the lead pair 22 provides heating current for cathodes of the lamps 12 and 14, while power for driving the lamps in series is provided between the lead pairs 20 and 24. The ballast 10 is connected to an AC 20 power source through two leads 30 and 32.

 Fig. 2 illustrates one embodiment of the gas discharge lighting control apparatus of the present invention. To facilitate illustration, conventional fluorescent lamps are used as a specific example of the 25 gas discharge lamps. However, the applicability of the invention to other gas discharge lamps including mercury vapor, sodium vapor, and metal halide should be clearly understood. While only fluorescent lamps are shown in the embodiment, the application of the invention is easily 30 expandable to more than two lamps.

 In Fig. 2, a first embodiment of an integral ballast-control apparatus 40 according to the invention is shown connected to two fluorescent lamps 12 and 14 through three lead pairs 20, 22 and 24. The integral ballast-control 35 apparatus includes magnetics similar to that shown in the ballast 10 in Fig. 1, with the exception of an additional

winding 42 providing a low voltage source for control of the lighting system. A primary winding 44 of the magnetics or transformer is connected to an AC power source at a pair of leads 30 and 32 as in the case of the ballast 10 in Fig. 1. The integral ballast-control apparatus 40 further includes a starting capacitor 26 and a series capacitor 28 as explained above. Three secondary windings 46, 48 and 50 are connected through the lead pairs 20, 22 and 24, respectively, to the fluorescent lamps 12 and 14. Energy to heat cathodes of the two lamps 12 and 14 is coupled from the lead pair 22 through the winding 48. The voltage across the lead pair 22 is typically about 3.6 volts as a result of the ratio of windings on primary 44 opposed to the winding 48. The multi-winding transformer is preferably wound on a laminated iron core, and the laminations interleaved to lower magnetization current.

Control of the power delivered to the gas discharge lamps 12 and 14 is obtained through the use of a control circuit 60 and a controlled impedance 62. The winding 42 includes a smaller number of turns than the primary winding 44 in order to achieve a step-down of voltage. In a conventional 120 volt system, the winding 42 preferably provides about 18 volts AC between the output leads. This 18 volt signal serves as a power input for the control circuit 60.

The controlled impedance 62 has its main current conduction path coupled from the primary winding 44 to one of the secondary windings. The control circuit 60 provides a time duration controlled drive signal to the control electrode of the impedance 62. In practice, the control circuit 60 is effective to drive the impedance 62 into or from a conductive state during a controlled portion of each half cycle of the AC line voltage.

The controlled impedance 62 is preferably a controlled switch which can provide either an open circuit

or a short circuit across its main conductive path, depending upon a control signal provided at the control electrode of the impedance. It will be appreciated that the state of the controlled impedance 62 (conductive or nonconductive) will determine whether the lamp current flows through the controlled impedance or not. When the controlled impedance 62 is in its conductive state, there exists a series circuit between the ballast and the lamps applying an operating current to the lamps. When the impedance is in a nonconductive state, heating current only is supplied to the cathodes of the lamps as detailed hereinafter.

The gate electrode 64 of the controlled impedance 62, which is a TRIAC in this example, is coupled to the output of the controlled circuit 60. In the absence of an activating signal at the gate, the TRIAC 62 presents a very high impedance between the primary 44 and the lamps. When an activating signal is applied at the gate, the TRIAC turns on, thereby presenting a low impedance (i.e. it becomes conductive) between the primary and the lamps. Thereafter, the TRIAC 62 remains conductive until the current flowing therethrough fails to exceed a predetermined extinguishing current. The TRIAC 62 conducts in both directions upon being triggered; however, the TRIAC will turn off during each cycle of an AC signal due to the current flow dropping below the extinguishing current when the AC signal changes direction. In the preferred embodiments, the TRIAC 62 is retriggered during each half-cycle of the power signal. By varying the delay before retriggering occurs, it is possible to control the proportion of each half-cycle over which TRIAC 62 conducts and thereby the overall power delivered to the lamps.

Fig. 3 illustrates an alternative integral ballast-control apparatus 40' connected to two fluorescent lamps 12 and 14 through three lead pairs 20, 22 and 24. The circuit is similar to that shown in Fig. 2 with the

exception that the control circuit 60 and the controlled impedance 62 are located between the primary winding 44 and one of the lead pair 20 to the lamp 12. Operation of the integral ballast-control apparatuses 40 and 40' is identical and will be explained hereinafter in detail. In the case of either integral ballast-control apparatus 40 or 40', when the controlled impedance 62 is in a conductive state, power is provided to the lamps 12 and 14 by the conduction through the controlled impedance. Power is provided to the lamps during nonconduction of the controlled impedance 62 but in an amount considerably less than the power provided during conduction and is intended only to provide heating of the cathodes while the lamps are waiting for the next conductive state of the controlled impedance 62. The control circuit 60 of Figs. 2 and 3 further includes a lead pair 66 intended to be connected to a photocell for a purpose to be understood through the description hereinafter relating to the operation of the integral ballast-control apparatus.

The integral design of the ballast and control circuit simplifies the magnetics involved and the circuitry necessary to control illumination of the lighting arrangements, and improves power factor.

Referring to Fig. 4, there is shown in block diagram format the current regulating functions of the control circuit 60. Broadly stated, the control scheme consists of two feedback loops, a first loop controlling lamp current within boundaries set by a limiter, and a second loop controlling lighting intensity. The first loop sets lamp current to a specific value. This first loop is indicated in Fig. 4 by dashed line connections and includes means monitoring lamp current by sampling the current through the main conduction path of the controlled impedance 62. The lamp current is converted into a voltage by a current-to-voltage transducer 70 resulting in a voltage V_C proportional to a current monitored at the

cathode of the impedance 62. This signal is a direct function of the lamp current, the parameter used in current regulation by the circuitry. The second feed-back loop compares the output of a photocell with a reference
5 signal. As illustrated in Fig. 4, the photocell 72 is positioned to intercept a portion of the irradiance from the gas discharge lamps 12 and 14 and thus produce a signal which is proportional to the output illumination level of the lamps and the ambient light level in the
10 immediate vicinity.

A comparator means 74 compares the output of the photocell 72 with a reference signal, V_{REF} , which may be established either internally or externally (not shown). The output signal of the comparator 74 is supplied to an
15 integrator 76, which functions to attenuate responses caused by ambient lighting perturbations or the like. In order to restrict the output signal of integrator 76 to boundaries within the dynamic range of a given lamp configuration, the output of the integrator is connected
20 to a signal limiter 78. The first and second control signals produced by the first and second loops, respectively, are supplied to a summing means 80, which produces a differential signal, V_{ERROR} . Clearly, if no correction is necessary, the first and second control
25 signals would be identical and V_{ERROR} would be equivalent to zero. The differential signal from the summing means 80 is supplied to an integrator means 82 in order to integrate the differential signal with respect to time. This integrated signal is then supplied to the input of a
30 voltage-controlled one-shot means 84 which controls the firing of the controlled impedance 62. The output of the integrator 82 advances the timing of the voltage-controlled one-shot means 84, which in turn advances the firing of the controlled impedance 62.

35 The operation of the control circuitry can be best illustrated by assuming that there is a positive error,

+V_{ERROR}, between the set point and the lamp current. This positive error causes the output of the integrator 82 to increase with time and thus advance the timing of the voltage-controlled one-shot 84. This in turn causes the controlled impedance 62 to trigger earlier in the voltage cycle, increasing the current fed to the lamps 12 and 14. When the differential signal from the summing means 80 approaches zero, i.e. V_{ERROR} equals zero, the output from the integrator means 82 ceases to increase and the timing of the controlled impedance firing during the voltage cycle remains unchanged.

To assist one skilled in the art in the practice of the present invention, Fig. 5 illustrates a circuit diagram for a specific embodiment with a two-fluorescent lamp configuration for the integral modular lighting control 40. This description treats the embodiment of the invention as depicted in Fig. 2. For simplicity, the windings 42 and 44 of Fig. 2 are shown as separate windings in Fig. 5. It should be understood that the embodiment of Fig. 3 is easily accommodated with a few changes in electrical connections. The controlled impedance 62 comprises a TRIAC with its main current conduction path coupled between the gas discharge lamp lead pair 24 and a current sensing resistor 86.

The winding 42 is connected to a diode bridge 90 including four diodes D₁ to D₄, which provide rectified power for the control circuit 60 and 60 hertz synchronization for the one-shots discussed above. A transistor 92 and a resistor 94 comprise a series regulator maintaining a given voltage for the control circuit supply, typically about 10 volts. A photocell (not shown) is placed in a bridge connection with three resistors 96, 98 and 100 by connection to the lead pair 66. The reference for the bridge configuration of the photocell may be set mechanically with a shutter mechanism covering the photocell from irradiation by the lamps or

electronically by adjusting the bridge resistors themselves.

The integrator 76 used in the second control loop is formed by a resistor 102, a capacitor 104 and an
5 operational amplifier 106. The output signal from the integrator 76 is applied to a resistive network including three resistors 108, 110 and 112. This resistor network comprises the signal limiter 78, the upper and lower boundaries of which are set by the values of the resistors
10 108 and 110, respectively.

The output from the limiter 78 is compared with the voltage representing half-cycle lamp current, the output of the first control loop discussed above. This first control loop output is obtained by deriving a signal
15 proportional to the current through the main conduction path of the TRIAC 62 and converting this current signal to a voltage through the current-to-voltage transducer 70. The transducer 70 includes a transistor 114. In operation, a voltage appears across the resistor 86 which
20 is proportional to the amount of current being conducted through the main conduction path to the controlled impedance 62. The transistor 114 is supplied from a point between the resistor 86 and the controlled impedance 62. Consequently the voltage seen by the transducer 70 is
25 proportional to the current conducted by the controlled impedance 62. The difference between the limiter 78 and the current-to-voltage transducer 70 is obtained as a result of the summing means 80 as noted above. This difference is applied to the integrator 82 which includes
30 a resistor 116, a capacitor 118 and an operational amplifier 120.

An integrated circuit 122 comprises a dual timer arranged in two one-shot configurations. The voltage V_T is applied at a terminal 125 coupled by a resistor to an
35 input pin of the integrated circuit 122. The first one-shot configuration is triggered at the zero crossing of

the line voltage i.e. the a.c. power supply voltage supplied to the complete lighting system at, e.g. 110 volts, and is controlled by the output from the integrator 82. The second one-shot is in turn triggered
5 by the trailing edge of the output from the first one-shot. The output from the second one-shot is supplied to the base of a transistor 124 which is in turn used to trigger the gate 64 of the TRIAC 62.

While emphasis has been placed herein on preferred
10 embodiments of the invention and the specific structures and structural interrelationships of the component parts thereof, it will be readily apparent that many different embodiments of the invention can be made and that many changes can be made in the embodiments herein illustrated
15 and described without departing from the principles of the invention. Accordingly, it is to be understood that the foregoing descriptive matter is to be interpreted as merely illustrative of the invention and not as a limitation.

CLAIMS

1. A circuit for controlling the output illumination of one or more gas discharge lamps, the circuit comprising magnetic ballast means for providing power to the one or more gas discharge lamps, and characterised by
5 a controlled impedance so coupled between the magnetic ballast means and the one or more gas discharge lamps as to control the flow of lamp discharge current; and
circuit means for controlling conduction of the
10 controlled impedance to cause illumination of the one or more gas discharge lamps, the circuit means being responsive to deviation of lamp current from a predetermined value and receiving power and synchronizing signals from the magnetic ballast means.
15
2. A circuit according to claim 1, characterised in that the circuit means includes a timing means initiated by the start of each half-cycle of an AC power input signal supplied thereto via the magnetic ballast means and
20 is adjustable to indicate a selected delay beyond the start of each said half-cycle.
3. A circuit according to claim 2, characterised in that the controlled impedance comprises a TRIAC.
25
4. A circuit according to claim 1, characterised in that the lighting system comprises a pair of series connected gas discharge lamps.
- 30 5. A circuit according to claim 4, characterised in that the magnetic ballast means includes a plurality of windings adapted to be connected to cathodes of each of the one or more lamps, the windings providing heating
35 power to the or each lamp, and the or each lamp being a hot cathode fluorescent lamp.

6. A circuit according to claim 4, characterised in that ballast means includes a multi-winding transformer wound on a laminated iron core, and the laminations are interleaved to lower magnetization current in the ballast means.

7. A circuit according to claim 1, characterised in that the circuit means includes a first and second control loop arrangement, the first control loop functioning to control lamp current within boundaries of a limiter, the second control loop functioning to compare a signal proportional to the lamp illumination level with a reference signal and further to provide or deny a drive signal for the controlled impedance.

8. A circuit according to claim 3, characterised in that the TRIAC has its main current conduction path coupled between an output of the magnetic ballast means and the gas discharge lamp, the TRIAC being responsive to the said drive signal to provide current conduction between the ballast means and the said lamp during at least a portion of each AC voltage half-cycle.

9. A method for controlling the output illumination of one or more gas discharge lamps in a lighting system, the method comprising the following steps:

supplying AC power to a primary winding of a transformer means to provide power for operation of the one or more gas discharge lamps; and controlling conduction of a controlled impedance series coupled between the transformer means and a first connection of the one gas discharge lamps, the transformer means being coupled to a second connection of the one gas discharge lamp, and the controlled conduction of the controlled impedance being varied in response to deviation of lamp current from a predetermined value, characterised in that

the lamp discharge current is interrupted by the controlled conduction of the controlled impedance, and power and synchronizing signals utilized in controlling the conduction of the controlled impedance are obtained
5 via the transformer means.

10. A method according to claim 9, characterised in that the said controlling step includes sensing the overall illumination in an area lighted by the lamp or lamps and
10 adjusting the conduction time of the controlled impedance to maintain the overall illumination at a constant level.

11. A method according to claim 9 or 10, characterised in that the length of time of conduction of the controlled
15 impedance is adjusted during each half-cycle of the AC power signal.

12. A method according to claim 9, 10 or 11, further characterised by the step of supplying a constant cathode
20 heating power to the gas discharge lamp.

13. A method according to any one of claims 9 to 12, characterised in that the controlled impedance has predefined conductive and noneconductive states.
25

14. A method according to any one of claims 9 to 13, further characterised by the step of controlling the length of time which the controlled impedance remains in its conductive state in relationship to the desired
30 illumination of the said lamp during each cycle of the AC power signal.

15. A circuit for controlling the output illumination of one or more gas discharge lamps, the circuit comprising
35 transformer means for providing power to the one or more gas discharge lamps and having a primary winding to

be connected to a source of AC power and a plurality of secondary windings;

a controlled impedance coupled between the transformer means and the one or more gas discharge lamps;
5 and

control means for controlling conduction of the controlled impedance, the control means being responsive to a change in lamp current;

the said one gas discharge lamp being connected in
10 electrical series with a pair of the said secondary windings, characterised in that the control means receives power and synchronizing signals from the transformer means.

15 16. A circuit according to claim 15, characterised in that the controlled impedance comprises a TRIAC.

17. A circuit according to claim 16, characterised in that a current detection means is coupled to a cathode of
20 the TRIAC.

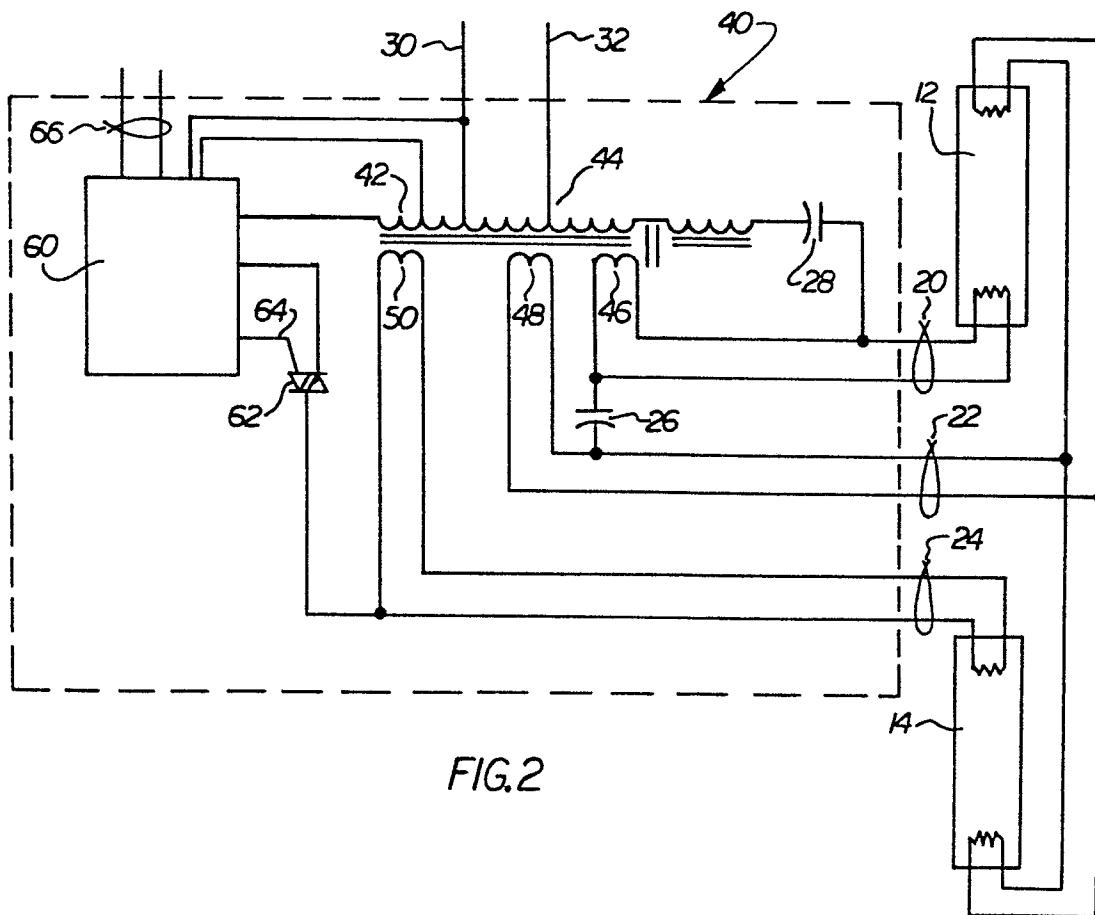
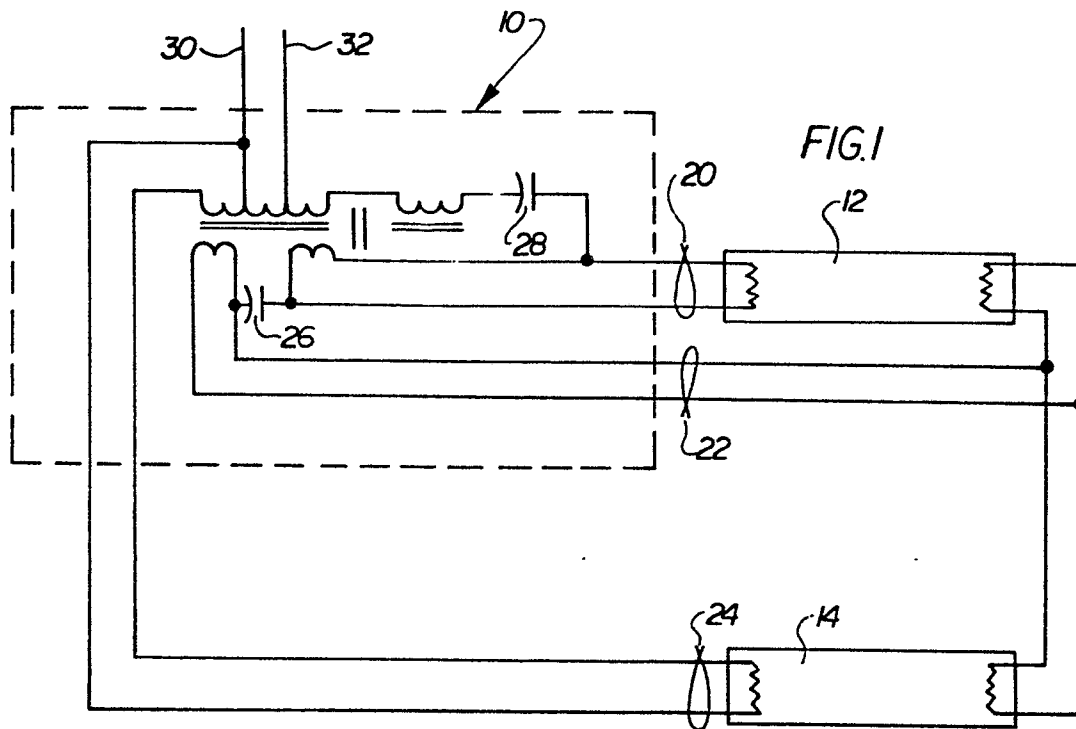
18. A circuit according to claim 17, characterised in that the current detected at the cathode of the TRIAC is coupled to circuit means to provide a current regulation
25 signal used to regulate lamp current.

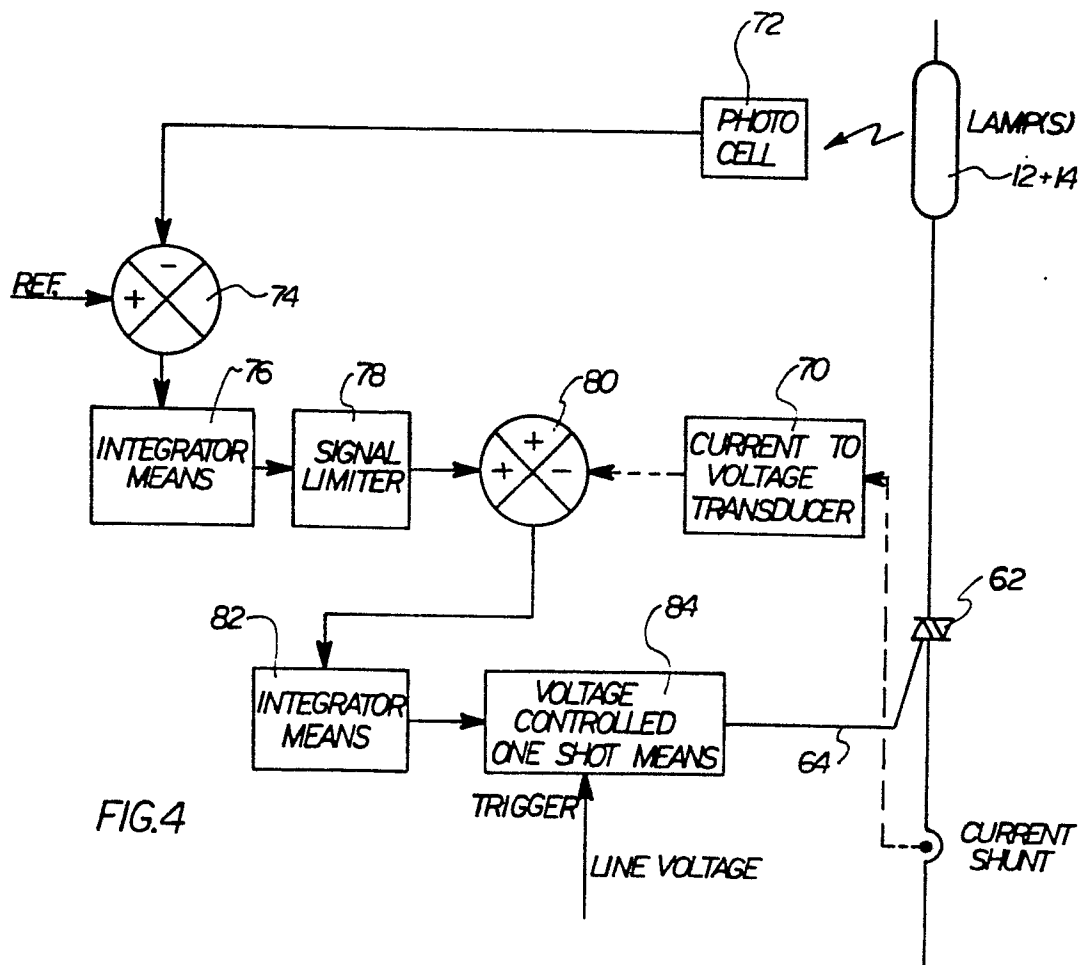
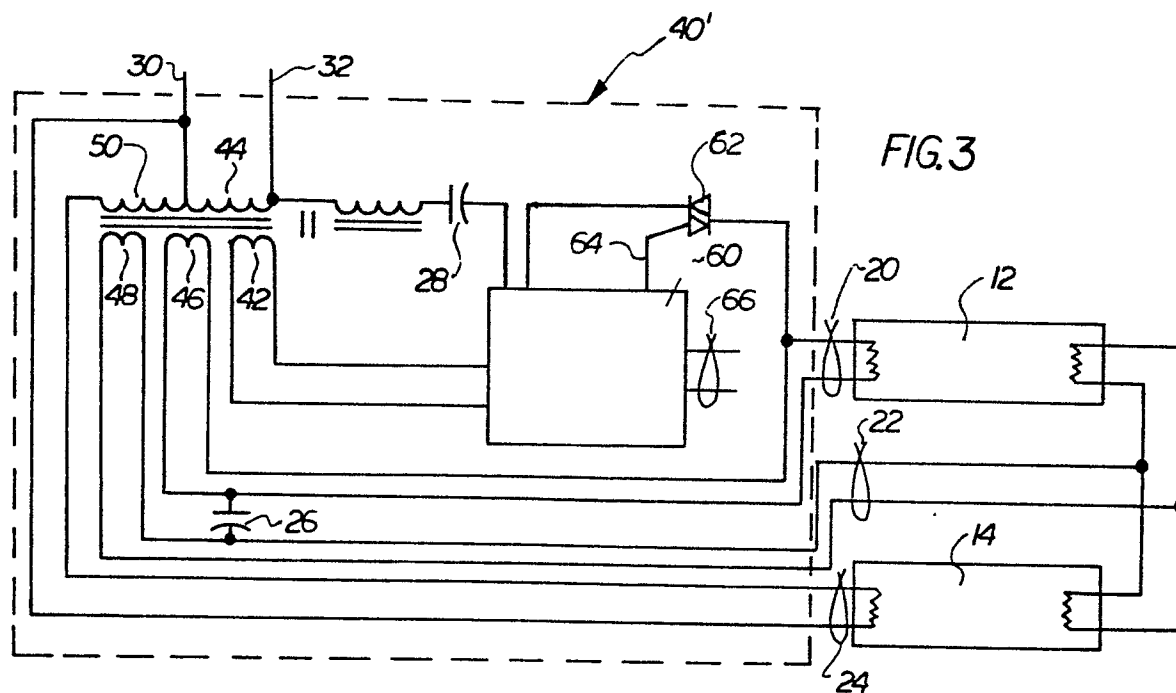
19. A circuit according to claim 18, characterised in that the transformer means has a core of interleaved laminations to reduce magnetization current.
30

20. A circuit according to any one of claims 15 to 19, characterised in that the means for controlling conduction includes a first and second control loop arrangement, the first control loop functioning to control lamp current
35 within boundaries of a limiter, and the second control loop functioning to compare a signal proportional to the

lamp illumination level with a reference signal and to provide or deny a drive signal.

21. A circuit according to claim 20 when dependent on
5 claim 16, characterised in that the TRIAC has its main
current conduction path coupled between an output terminal
of the transformer means and the gas discharge lamp, and
the TRIAC is responsive to the said drive signal to
provide current conduction between the transformer means
10 and the said lamp during at least a portion of each AC
voltage half-cycle.





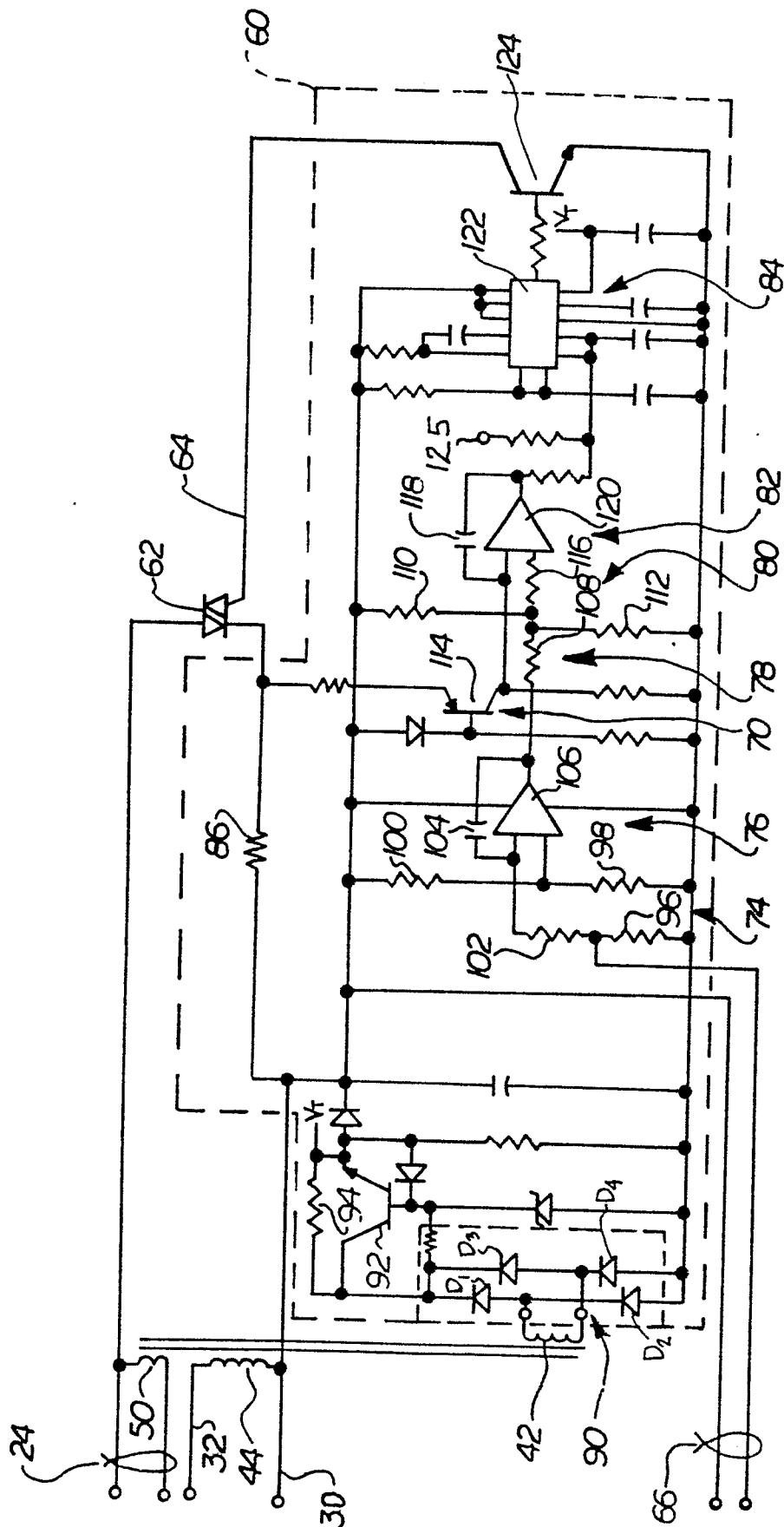


FIG. 5



European Patent
Office

EUROPEAN SEARCH REPORT

0083992

Application number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP-83300124.1
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	WO - A1 -79/00 615 (ELSTROM) * Abstract; fig. 1,2; page 5, line 10 - page 13, line 17 *	1-3,7,11,13	H 05 B 41/392
Y	DE - A1 - 2 912 690 (ESQUIRE) * Fig. 2; page 16, line 10 - page 19, line 4; claims 1,2; 7,9; page 15, line 1-7 *	1-4,7,9,10,13	
Y	US - A - 3 894 265 (HOLMES) * Fig. 1,7; abstract; column 9, line 63 - column 10, line 20 *	1-4,7,13	
Y	DE - B2 - 2 262 629 (THEIMER) * Fig.; Column 3, line 20 - column 4, line 33; claims 1,3 *	1,7,9,10,13	TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A,D	US - A - 4 197 485 (NUVER) * Totality *		H 05 B 41/00
A,D	US - A - 4 207 418 (SPIRA) * Totality *		
A,D	US - A - 4 207 497 (CAPEWELL) * Totality *		
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 08-04-1983	Examiner DIMITROW
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			

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EUROPEAN SEARCH REPORT

Application number

EP 83300124.1

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	<u>US - A - 3 845 350 (LUURSEMA)</u> * Totality * -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl. ³)