

[54] REMOTELY CONTROLLED DISCHARGE
LAMP DIMMING MODULE[75] Inventor: Robert J. Petrina, Costa Mesa,
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[58] Field of Search 315/DIG. 4, 194, 195, 199,
315/291, 294, 200 R, 201, 205

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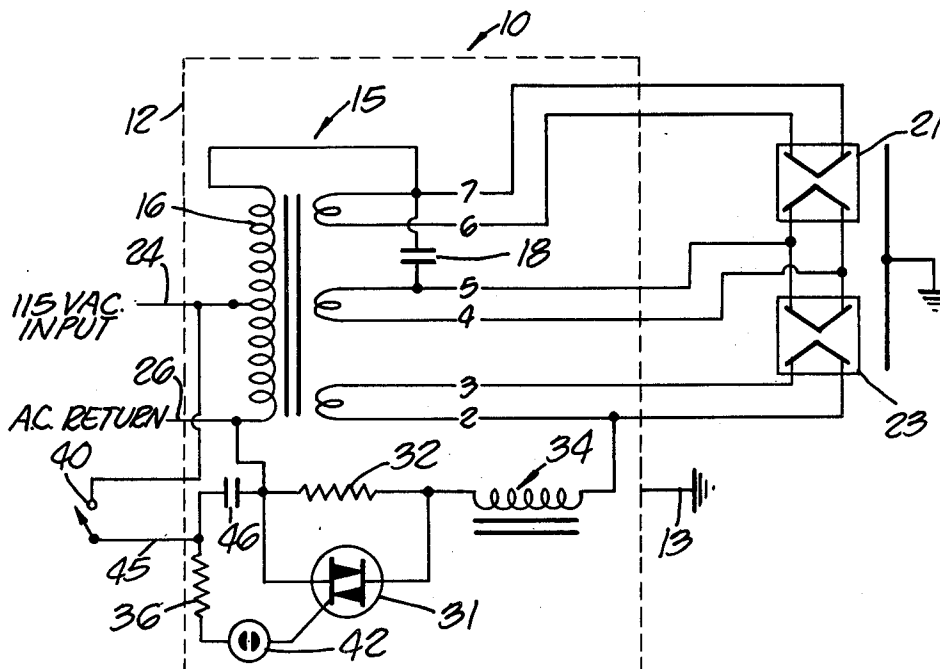
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[57] ABSTRACT

A remotely controlled and shielded module for dimming discharge lamps such as fluorescent tubes includes a solid state gating element which is biased to a conducting or non-conducting state by a gate trigger circuit. When biased to a conducting state, full current is applied to the lamps associated with each module, and when in a non-conducting state, current applied to the lamps is reduced by a dimming resistor. One or more lamps and one or more modules may be remotely controlled with the advantage that all circuit components except the control element and the lamps may be housed in a shielded module and controlled by a remote controller which controls the gate trigger circuit in the module. The described dimming module is especially useful for aircraft and the like, and those instances in which a dimming operation is needed in an environment in which electromagnetic interference would be objectionable.

3 Claims, 4 Drawing Figures



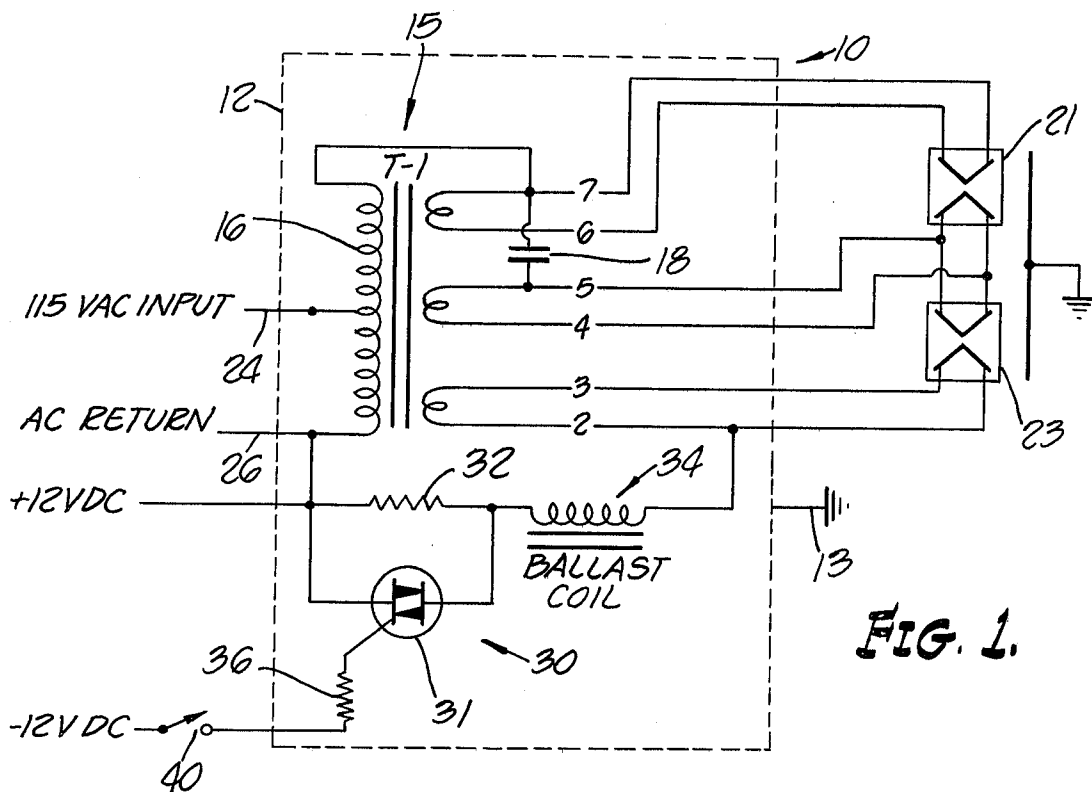
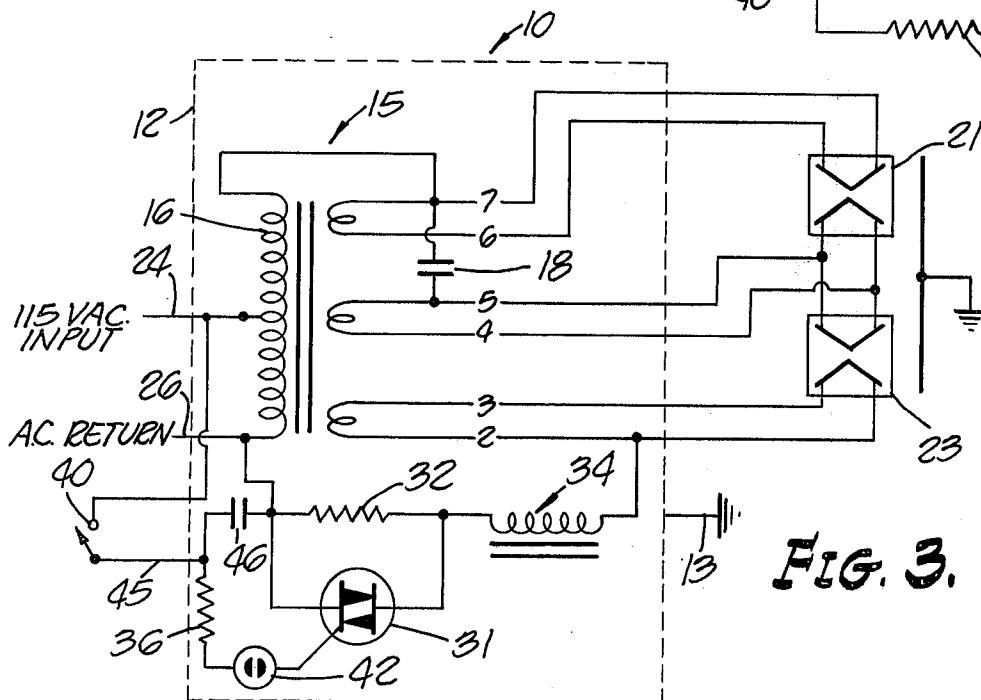
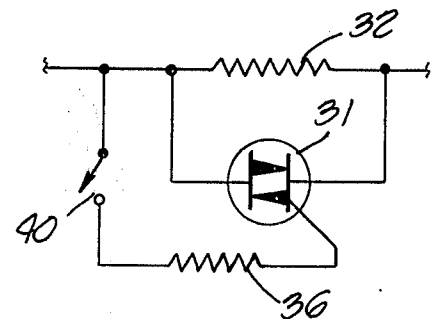


FIG. 2.



REMOTELY CONTROLLED DISCHARGE LAMP DIMMING MODULE

BACKGROUND OF THE INVENTION

This invention relates to a dimming device, and more particularly to an improved shielded module containing the circuit components for dimming discharge lamps such as fluorescent tube type lights.

Discharge lamps such as fluorescent tubes present particular problems when systems requirements include dimming. All discharge lamps require accessory equipment to start and operate the lamps within their particular ratings. When dimming is required, these accessories become more complicated and expensive in addition to being bulky and heavier. These facts compound the structural requirements of the associated lighting fixtures as well as adding to the wiring and maintenance expense.

For lighting installations when size and weight are critical, such as aircraft, the present additional dimming accessories result in serious compromises.

With the advent of reliable semiconductor components for power control, many electronic systems have been devised to reduce the size, weight and expense of the control accessories. Much technology has been demonstrated to date for motor, electrical heater and incandescent lamp control using solid state components. The discharge lamp, however, has presented particular problems due to the basic nature of its operation.

Solid state approaches have typically resulted in only minor improvements in size and weight of the dimming accessories while providing only limited control range with poor system reliability under environmental extremes of temperature. In addition, these solid state components have also resulted in additional electromagnetic interference to adjacent electrical and electronic equipment. Typical present systems are further subject to electrical supply surges and transients which further compromise the system performance and reliability.

Discharge lamps operate on an arc stream principle which causes them to require a certain ionizing potential before any current flows between the cathode terminals, contrary to an incandescent lamp where a continuous filament exists between terminals and current flows at any applied voltage. Due to this inherent characteristic of discharge lamps, the controlling accessory, typically referred to as a ballast transformer, is loaded only during the period of each half cycle when the voltage is above the ionizing potential of the particular lamp or lamps.

In dimming applications, it is important that the voltage applied across the discharge lamp terminals be maintained at a high level and that dimming be accomplished by varying the series current limiting impedance between the limits of rated current and some low value of current, such as 1% of rated.

This variation in the series current limiting impedance can be accomplished in several ways well known to those skilled in the art. Most systems result in large, and heavy magnetic, capacitive or resistive components which further require cumbersome or power dissipative control elements. Some of these techniques are limited in performance and require large, expensive magnetic components that compromise either control range or system watt losses.

Discrete step dimming may be accomplished by using a resistor or resistors. Such a system provides satisfactory operation of the discharge lamps but does result in power losses in the resistor elements. Continuous dimming may further be accomplished by using a continuously variable rheostat, with a tapered winding and with sufficient current rating to dissipate the watt loss at any setting. A linear wound rheostat may also be used with a fixed resistor in order to keep the rheostat size reasonable. This system limits the maximum current level through the lamps with a resultant loss in light output. These systems can typically result in 50 percent input power watt loss compared to non-dimming circuits.

SUMMARY OF THE INVENTION

Solid state technology has made available many types of transistor and thyristor devices which are capable of controlling large amounts of power with very low level control signals. Such a device is currently known commercially as a "Triac", which is basically two thyristors back to back in a single enclosure. This arrangement provides a full wave control capability as well as making the device more reliable in that it is self-protected against reverse breakdown.

The Triac is the essential element in providing a compact, low cost, efficient and reliable dimming circuit for discharge lamps. Because of these capabilities, all functional elements of such a dimming circuit can be located within the ballast transformer enclosure which simplifies the overall system and permits effective shielding and filtering of any electromagnetic interference associated with the switching action of the Triac. Only a single external control element or a control voltage is needed for full range dimming of the lighting circuit.

Furthermore, one control element or control voltage can effectively control any number of ballast transformer/lamp circuits.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a dimming circuit device in accordance with this invention illustrating a form in which control of a high-low dimmer is by a secondary power source;

FIG. 2 is a partial schematic showing a modification of FIG. 1 in which the principal source of power may be used;

FIG. 3 is a schematic diagram of a modified form of the dimming circuit device of FIG. 2 in which several modules, of the type illustrated in FIG. 3, may be operated from the same controller; and

FIG. 4 is a schematic diagram of a dimming circuit device in accordance with this invention illustrating a form usable for continuous dimming from a principal power source.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Several different forms of the preferred embodiment will be described hereinafter. Thus, referring to FIG. 1 a shielded and remotely controlled dimming circuit is illustrated, and includes a circuit module 10 in the form of a shielded housing 12 grounded as indicated at 13. The module also includes a circuit board (not shown) on which the electronic components are mounted in the usual manner. The shielded housing, board and

components are assembled on a shielded base plate in the usual manner. In this way, all of the components within the module are surrounded by shielding material which substantially eliminates any electromagnetic interference created by the module components.

Located within the housing is a ballast-transformer circuit generally indicated at 15 including a transformer 16, with a lamp starting capacitor 18 in the secondary windings as indicated. The output leads of the secondary winding are connected to the lamps 21 and 23 as illustrated. Power for the ballast-transformer circuit 15 is supplied through leads 24 and 26 which extend through the wall of housing 12. It will be observed that the output leads of the secondary windings also extend through the wall of the housing 12 as indicated schematically in FIG. 1.

The housing 12 also contains a gating circuit generally indicated at 30, the gating circuit including a solid state gate thyristor device 31 which is connected in parallel with a dimming resistor 32. In series with the dimming resistor is a ballast coil 34. The thyristor 31 is triggered through a gate trigger which includes resistor 36, the gate trigger control means being switch 40 which is located externally of the housing as indicated.

In the form shown in FIG. 1, a 12-volt power supply is used as a secondary power source for control of the gating circuit, the primary source of power being 110-volts A.C. at 60 H.Z. or 400 H.Z., optionally.

As indicated, the thyristor device is a solid state gating device for full wave control of relatively large amounts of electrical power by a relatively low level biasing electrical input signal, the signal being applied, in the form shown in FIG. 1, through the gate trigger means. The thyristor 31 is capable of being biased for constant conduction in one state, and for non-conduction in another state.

In the form shown, the circuit of FIG. 1 operates as an "on/off" switch to provide either high or low dimming control. As shown, with switch 40 closed, the thyristor device 31 will be in the conducting state with each zero crossing of the A.C. current, with the result that virtually 100 percent of the lamp bypasses the dimming resistor 32, and the fluorescent lamps 21 and 23 operate in the bright condition.

When switch 40 is opened, no gating energy reaches the thyristor device 31, and it is in the non-conducting state such that it does not conduct at any portion of the A.C. current wave. Lamp current now passes through resistor 32, which functions as a dimming resistor, the value of the resistor 32 being selected to set the level of dimming of the lamps 21 and 23.

In the form shown in FIG. 1, any number of individual modules may be controlled from a common source of D.C. voltage or current. One of the advantages of this type of arrangement is that a single switch, 40, may be used to control any number of modules and their associated lamps. Since each of the thyristor devices and each of the modules is isolated from the remaining by either being in the conducting or non-conducting state, there is no interaction between the several individual ballast modules operated from the common source of D.C. voltage or current.

As illustrated, each ballast lamp current returns directly to the A.C. supply, either by way of the dimming resistor 32 or by way of the thyristor device in the conducting condition, and there is no interaction between the individual ballast circuits controlled.

In the form shown in FIG. 2, the thyristor circuit elements are arranged such that no external energy source is needed for triggering. In the form shown, wherein like reference numerals have been applied where applicable, lamp current is used on each half cycle to trigger the thyristor. Since lamp current flows in the gate circuit in this arrangement, each module is operated by its own separate switch 40.

FIG. 3 shows a modified form of the circuit of FIG. 2 in order to permit several different modules to be controlled by a single switch without interaction between the severally controlled modules.

This arrangement of FIG. 3 uses a single neon lamp 42 and resistor 36 in the trigger circuit and uses energy directly from the A.C. power input to the ballast. Any number of modules of the type of FIG. 3 may be connected in parallel at junction 45 and a single remote switch 40 will control all modules. The thyristor 31 is arranged so that lamp current does not flow in the gate circuit hence no interaction between individual module circuits will occur.

Triggering will occur in each half cycle in advance of the lamp current, since the neon lamp discharges when the input voltage rises to a predetermined voltage, e.g. approximately 40 volts RMS. Lamp current has a lagging power factor because of the inductive ballast coil 34. The lamp current wave crosses zero at a time just after the thyristor gate has been triggered by the neon lamp 42. The net result is that the thyristor starts conducting at zero crossing of the lamp current wave and continues for each full half wave. This results in full lamp current passing through the thyristor 31 on each half cycle and provides the bright operating condition for fluorescent lamps 21 and 23.

When switch 40 is open, no triggering occurs and resistor 32 limits lamp current to the selected dim condition. Capacitor 46 provides filtering on the control line 45 to bypass any stray pick up when switch 40 is open.

The circuit shown in FIG. 3 provides the several desirable features such as, simple switch closure control for dim/bright control. Moreover, a secondary energy source is not needed for the triggering function. Multiple modules may be controlled by one common switch, and there is no interaction between the multiple modules. Due to triggering at zero crossing of lamp current, there is low electromagnetic interference. Also important is the fact that all dimming circuit components are located inside the module housing (except for the external control) for economy and shielding.

A functional circuit for full range dimming of two series operated fluorescent discharge lamps is illustrated in FIG. 4, wherein like reference numerals have been used where applicable. This circuit provides for smooth, continuous control of the light level using a single external control element or control voltage to set the desired light level of any number of individual ballast-transformer lamp circuits. This control element or voltage may be remotely located with no degradation of the control function.

This basic circuit may be applied to various combinations of lamps, supply voltages and power frequencies, or lamp power ratings without departing from the basic concept of this discharge lamp dimming system. The complete functional diagram, FIG. 4, includes components and circuits that provide proper rapid start lamp operation, electromagnetic interference filtering,

power factor correction and thyristor trigger control functions.

As illustrated in FIG. 4, capacitor 47 is a ($\pm$) phase capacitor in conjunction with resistor 48 which is a ($\pm$) phase resistor. Resistor 36 is a (-) phase resistor in series with capacitor 51 which is a (-) phase capacitor. The trigger circuit includes an R.C. circuit of trigger capacitor 53 and trigger resistor 54. The remaining components of the circuit include filter capacitors 55, 56, 57, and a power factor capacitor 58 in series with a power factor fuse 59. A thermal protector 60 is in the input line.

A filter choke 65 is associated with the thyristor 31, the choke having a filter damper network of filter capacitors 66, 67 and damper resistor 68 associated therewith, as illustrated. Resistors 70 and 71 are low level set resistors and function as dimming resistors in parallel with the thyristor output.

The circuit and module of FIG. 4 is a unique arrangement of phase control elements whose principal function is to provide proper trigger timing for the thyristor gate for full range dimming control of lamps 21 and 23 associated with the module. With the control 75, located externally of the module, set for maximum light output, capacitor 47 and resistor 48, connected in parallel, yield approximately a $+45^\circ$ phase shift of the trigger control voltage while resistor 36 and capacitor 51, connected as shown, yield approximately a -45° phase shift of the trigger control voltage. The net result is that the opposing phase shifts of $+45^\circ$ and -45° cancel to yield a 0° phase shift control voltage for the trigger circuit consisting of the neon lamp 42 and R.C. components 53 and 54.

The phase angle of the lamp current under these conditions lags approximately -45° , as a result of the inductive ballast element 34. Hence, the triggering occurs in advance of each half wave of lamp current. This insures that maximum lamp current will be realized.

On the low light level condition, the trigger voltage is delayed approximately -90° for the trigger circuit by the action of capacitor 47 and resistor 48 now functioning in series along with resistor 36 and capacitor 51.

Under low level conditions, lamp current is determined principally by the dimming resistor in the circuit since the triggering is delayed -90° while the phase angle of lamp current is approaching 0° . Since the majority of the impedance in the lamp circuit is resistive, and due to the phase angle relationship of lamp current under this condition, there is low light output.

Thus, the circuit of the present invention provides a unique phase control operative to produce a phase shift control voltage variable between 0° through -90° to control the light output. The changes in lamp current phase, favor the control circuit function for effective dimming control. Accordingly, a full range of high level is provided, high level at 0° and progressively dimmer as the phase shift approaches -90° , with the lowest illumination being at -90° phase shift.

Circuit elements 66, 70 and 71 determine the low light output lamp current and may be suitably adjusted to suit the characteristics of the particular lamp or lamps being operated.

External adjustment of this dimming circuit between the extremes of maximum and minimum light output is provided by control 75 and may consist of either a power potentiometer or a variable transformer control.

Another unique feature of the dimming system of FIG. 4 concerns the small amount of power required to control each module circuit. Typical control current at 115 volt A.C. input is 0.010 ampere maximum, which represents less than 1 watt of control power and is independent of the power rating of the lamps in the dimming circuit. The components may be easily selected for satisfactory dimming discharge lamps with watt ratings as high as 100 watts per lamp. Moreover, ballast transformers are typically designed for operating two lamps, therefore, the dimming control circuit of FIG. 4 offers a high power-sensitivity compared with prior art fluorescent dimming systems.

Furthermore, since the external control 75 is fully isolated from the individual lamp circuits of each module, one basic control may be used to control any number of modules, such as may be required in a large installation, with no interactions between individual sets of lamps and modules.

In such a large installation, individual modules may be switched on or off with no effect on the operation or dimming control of the remaining ballast-transformers in the system.

By varying the setting of external control element 75 between the conditions of high light output, and the conditions of low light output, any level of light output may be selected with a smooth and continuous variation between these extremes. The low light level is determined by the system requirements or the low-level operating characteristics of the particular lamps being controlled.

A further advantage of the dimming system of FIG. 4 is that all control circuit elements are small and may be located inside each module housing, thus providing effective shielding. Only one exit wire is required for the control voltage which minimizes any special wiring for a full range dimming system.

Other advantages of the system of FIG. 4 include single basic control element or voltage, a single control for multiple modules by a remotely positionable dimming control. Moreover, lamp size, available system voltage or frequency are not limitations on the system. The unique voltage controlled phase triggering circuit is relatively simple with considerable reduction in power losses, less than 1 watt per ballast. Lamps of up to 100 watts per lamp may be controlled by the same circuit, and there is full isolation of individual units and the ballasts and lamps in multiple installations. With modifications, the present system may be used with capacitive ballasted lamp circuits.

While reference has been made to a neon lamp, it is understood that other devices may be used such as two avalanche diodes arranged back-to-back. The neon lamp, however, is preferred. Moreover, rather than a Triac, silicon controlled rectifiers may be used and further modification for their use include a pulse transformer with plural output windings to provide two gates.

Although exemplary embodiments of the invention have been shown and described, many changes, modifications, and substitutions may be made by one having ordinary skill in the art without departing from the spirit and scope of this invention.

What is claimed as the invention is:

1. An electromagnetic shielded and remotely controlled dimming circuit for a ballast-transformer operated discharge lamp lighting means comprising

a ballast-transformer module of electromagnetic shielding material, said module containing a ballast-transformer circuit including a starting capacitor in the secondary windings and output leads for connection to discharge lamps.

first means to supply electrical power to said ballast-transformer circuit.

solid state gate means within said module for full wave control of relatively large amounts of electrical power by a relatively low level biasing electrical input signal, said gate means being capable of being biased for constant conduction in one state and for non-conduction in another state.

gate trigger means in said module and connected to said gate means for biasing said gate means to one of said states, said gate means being so connected that during constant conduction full current is supplied to said ballast-transformer circuit.

dimming resistor means electrically in parallel with said gate means and being so connected that during non-conduction of said gate means current passes through said dimming resistor to supply less than full current to said ballast-transformer circuit.

gate trigger control means locatable externally of said module for controlling said gate trigger means, said first means also supplying power to said gate trigger means and said gate means.

said gate trigger means further including neon lamp means dischargeable above a predetermined voltage to permit flow of full current in said ballast-transformer circuit subsequent to biasing said gate means to a conductive condition and at a voltage below said predetermined voltage operative in cooperation with said dimming resistor to permit flow of less than full current, and

said gate trigger control means controlling at least two modules.

2. An electromagnetic shielded and remotely controlled dimming circuit for a ballast-transformer operated discharge lamp lighting means wherein said dimming circuit is a full range dimming circuit for at least two series operated discharge lamps comprising

a ballast-transformer module of electromagnetic shielding material, said module containing a ballast-transformer circuit including a starting capacitor in the secondary windings and output leads for connection to discharge lamps.

first means to supply electrical power to said ballast-transformer circuit.

solid state gate means within said module for full

wave control of relatively large amounts of electrical power by a relatively low level biasing electrical input signal, said gate means being capable of being biased for constant conduction in one state and for non-conduction in another state,

gate trigger means in said module and connected to said gate means for biasing said gate means to one of said states, said gate means being so connected that during constant conduction full current is supplied to said ballast-transformer circuit,

dimming resistor means electrically in parallel with said gate means and being so connected that during non-conduction of said gate means current passes through said dimming resistor to supply less than full current to said ballast-transformer circuit,

gate trigger control means locatable externally of said module for controlling said gate trigger means, said gate trigger means further including neon lamp means dischargeable above a predetermined predetermined to permit flow of full current is said ballast-transformer circuit subsequent to biasing said gate means to a conductive condition and at a voltage below said predetermined voltage operative in cooperation with said dimming resistor to permit flow of less than full current, and

said gate trigger means further including phase control means operative to produce a phase shift control voltage variable between 0° and through -90° for said gate means such that at 0° phase shift the current to said lamps is at a maximum and is at a minimum at -90°, and said current being between said maximum and minimum when said phase shift is at some value between 0° and -90°.

3. A circuit as defined in claim 2 wherein said ballast-transformer circuit includes inductive ballast coil means,

said neon lamp means and inductive coil means so cooperating with said gate means that as the gate trigger control means is actuated to a mode of bright operation of said lamp means full lamp current starts to flow through said gate means as the lamp current wave crosses zero and lamp current continues to flow for each full wave such that full lamp current flows for each half cycle of lamp current, and

said dimming resistor being operative to provide less than full lamp current flow as said trigger control means is actuated to a mode of low level operation of said lamp means.

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