

Nov. 8, 1966

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3,284,667

DIMMER CONTROL FOR SYSTEM HAVING MASTER AND SLAVE DIMMING

DEVICES USING PULSE SIGNALLING THEREBETWEEN

Filed Sept. 9, 1963

2 Sheets-Sheet 1

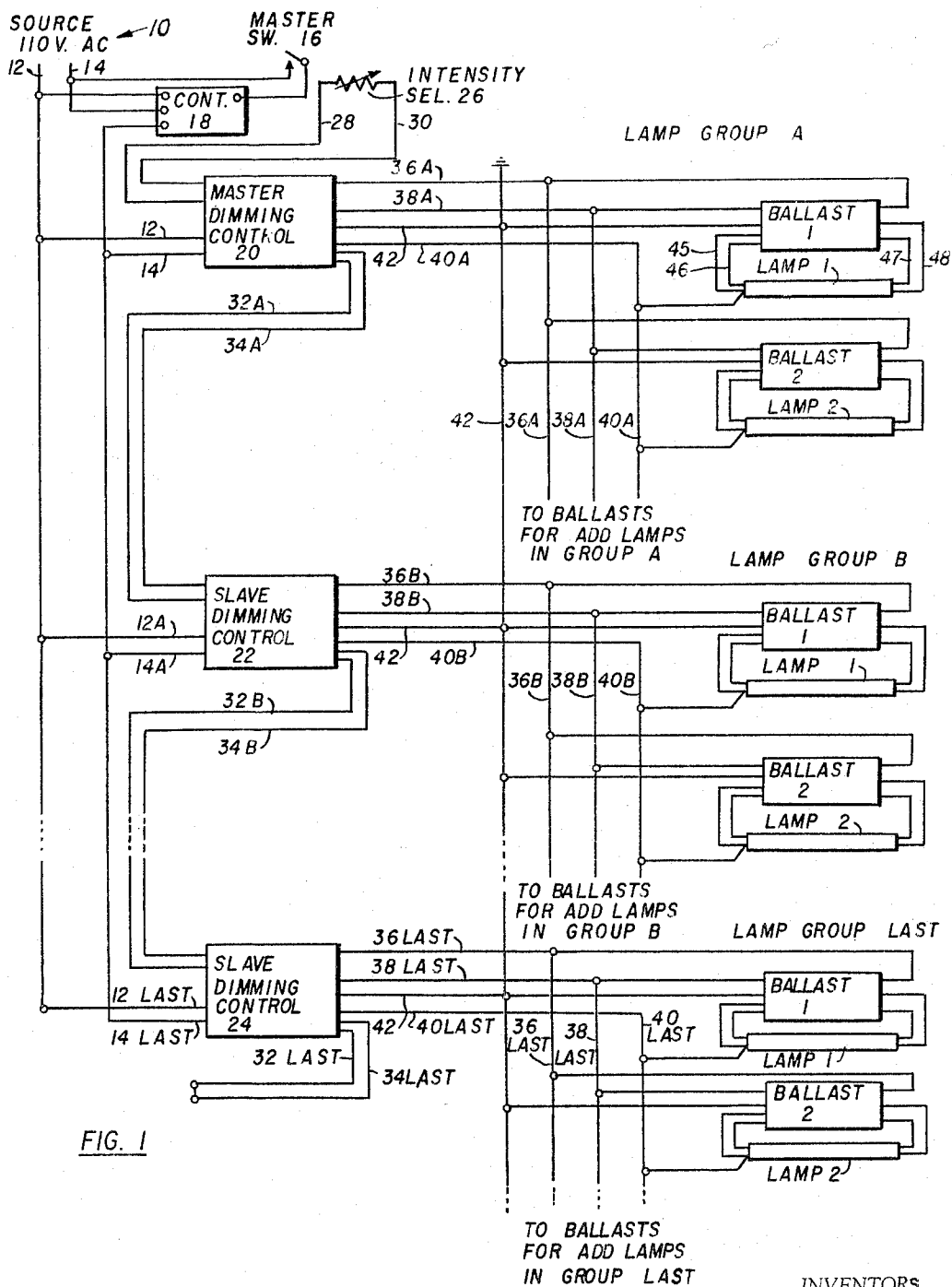


FIG. 1

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2 Sheets-Sheet 2

FIG. 2

DIMMING CONTROL

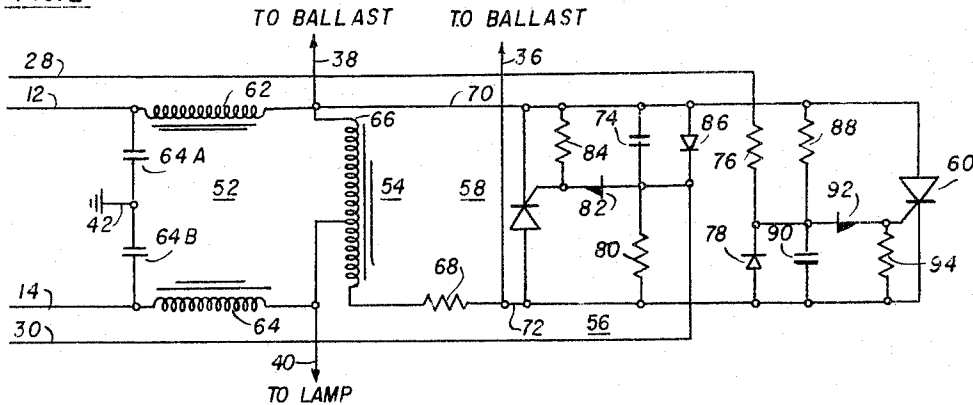


FIG. 3

MASTER DIMMING CONTROL 20

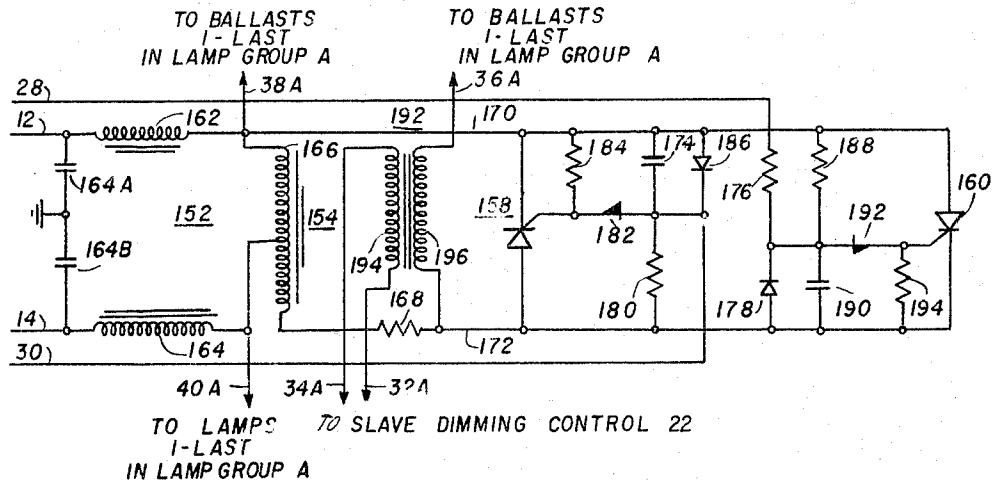
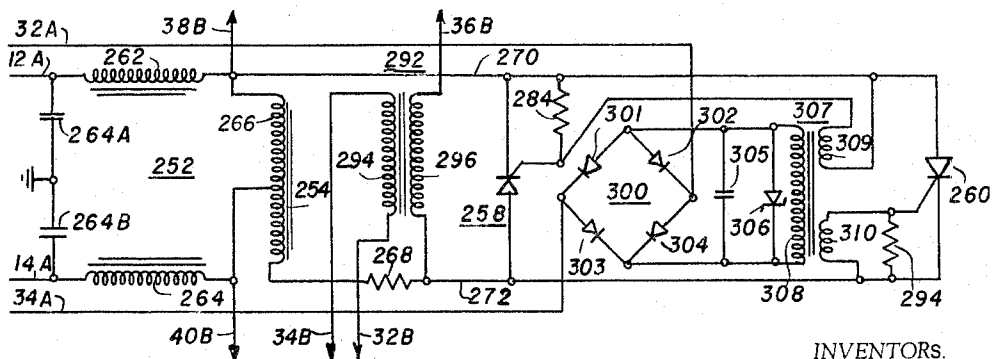


FIG. 4

SLAVE DIMMING CONTROL 22



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DIMMER CONTROL FOR SYSTEM HAVING MASTER AND SLAVE DIMMING DEVICES USING PULSE SIGNALLING THEREBETWEEN

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Filed Sept. 9, 1963, Ser. No. 307,667

15 Claims. (Cl. 315—195)

The present invention is directed to a novel electrical dimming system, and more particularly to a dimming system for varying the lumen output of a plurality of banks of lamps.

With the recent development of improved forms of control circuits, there has been a sharply increased use of lamp dimming systems both in the commercial and home fields. In one improved embodiment, a control switch is connected to adjust phase shift networks in the control of electronic switches to adjust the period of current conduction during each half cycle of an alternating voltage, the time of conduction being varied by adjusting the control switch to vary the current level for the lamps and the light output thereof. Such arrangement provides an excellent means for varying the level of the lamps over an extremely large range in a smooth and continuous manner. Unfortunately the number of lamps which may be operated from a circuit of this type is limited by the volt ampere rating of the electronic switches in the device, and such rating is not sufficiently high to permit connection of such circuit for use in the control of a plurality of lamp banks of the number frequently required in large commercial installations, factories, and the like.

In certain prior art attempts to overcome such problem, a plurality of individual systems of this type were connected with the control switches for each of the systems ganged together so that the turning of a single control member would effect operation of all of the control switches and thereby variation of the light output of all of the lamps in the installation. A particular shortcoming of such arrangement was the difficulty in providing a number of such systems which have operating characteristics such that the same lumen intensity would be provided by the different lamps with the operation of the single control member.

In a further development, a system was provided in which the master dimming circuit provided a signal to a plurality of individual slave dimming circuits, and the electronic switches in the master and each of the slave dimming units are operated at approximately the same time in each half cycle. A single intensity control device is provided in the master unit which adjusts the interval of current conduction of the master and each slave to the bank in the system. While such arrangement provided some improvement in the control lamp banks in the larger installations, certain serious shortcomings were inherent in such arrangement. That is, the signal provided by the master dimming circuit to each of the slave dimming circuits was necessarily a voltage having the magnitude and phase angle of the signal which is supplied by the master dimming circuit to the lamps connected to the master dimmer. As a result, it is necessary in such type arrangements to extend a separate set of conductors from the master to each of the slave units which is capable of conducting voltages in the order of that supplied by the source to the master dimming circuit (i.e., 118–120 volt signal). It is apparent that in existing installations, the running of an additional cable set which has suitable voltage and current conducting capabilities, is frequently expensive, difficult and time-consuming, if not impossible. Additionally, in larger

installations some variation in control can be expected by reason of the voltage drop which occurs between the widely separated locations in the system.

Of a more significant nature, however, the system was such that in addition to the connection of a control lead between master and slave units which had such conducting capacity, the master and slave dimmer units were necessarily connected to a common branch circuit of a source. Needless to say, the extension of the connections of each unit in a large installation for connection to the same branch circuit involves a substantial installation cost. The system has even less utility in existing installations in that the rearrangement of the branch circuits to accommodate such requirement is somewhat costly. Additionally, should circumstances require the rearrangement of the physical layout of a commercial building, the revision of such type wiring system to be consistent with the revised layout introduces serious problems.

It is an object of the present invention, therefore, to provide a novel master slave dimming arrangement of a more inexpensive nature which is capable of inclusion in existing plant layouts with a minimum of expense and alteration, while yet providing an improved form of control.

It is yet another object of the present invention to provide a basic dimming control which includes a minimum number of components having improved performance characteristics when used in regulating the lumen output of a plurality of fluorescent lamps, and which is readily adapted by minor modifications for use as a master circuit and slave circuits in a master-slave dimming arrangement for controlling a plurality of banks of lamps.

These and other advantages of the present invention will become apparent with reference to the following specification and accompanying drawings wherein basic embodiments of the structure are illustrated, and in which:

FIGURE 1 is a schematic circuit diagram of a novel master slave dimming circuit for controlling the light output of a plurality of lamp banks;

FIGURE 2 is a schematic circuit diagram of a novel dimming circuit for use in controlling the light output of a bank of lamps;

FIGURE 3 is a schematic circuit diagram of a master dimming control circuit including the basic dimmer structure of FIGURE 2; and

FIGURE 4 is a schematic circuit diagram of a slave dimming circuit incorporating the basic structure of the dimming circuits of FIGURES 2 and 3.

Master slave dimming circuit

With reference now to FIGURE 1, the master slave dimming circuit, as there shown, is connected to a source 10 which may comprise a conventional 110–120 volt source including a pair of conductors 12, 14. In the present disclosure, a master switch 16 and a contactor 18 are used to connect a master dimming control 20 and a plurality of slave dimming controls 22, 24, etc., to the same branch circuit or source 10. However, as will be apparent from the description hereinafter of the novel circuitry, the master dimming controls and slave controls may be connected to different branch circuits of a source which permits more flexible use of the system in existing, as well as new, installations.

An intensity selector resistor member 26 is connected over conductors 28, 30 to the master dimming control 20. As shown hereinafter, the lumen output of the master dimming control 20 and each of the slave dimming controls, such as 22, 24, are controlled by adjustment of the common intensity selector 26 to different positions. A first control circuit is extended from the master dimming control 20 over conductors 32A, 34A to the first slave dim-

ming control circuit 22, a second control circuit is extended from slave dimming control 22 over conductors 32B, 34B to the succeeding dimming slave control, etc. The output control conductors 32 Last, 34 Last of the last slave dimming control 24 are shorted as shown in FIGURE 1. It is apparent that a module arrangement of such type permits interconnection of an almost unlimited number of lamp banks while yet requiring a minimum of equipment. An installation having a total of six hundred lamps, for example, would include only one master control and forty-nine slave controls.

The master dimming control 20 shown in FIGURE 1 controls the light output of a first lamp group A, and each of the succeeding slave dimming circuits 22, 24 controls the light output of an associated lamp group, such as lamp B . . . lamp group Last. The connections between each dimming control, such as dimmer circuit 20, and its associated lamp group, such as lamp group A, comprises three conductors, such as 36A, 38A, 40A and a ground conductor 42.

Each lamp group, such as lamp group or bank A, comprises a plurality of from two to twenty lamps, such as lamp 1, lamp 2, etc., each of which lamps has a separate ballast, such as ballast 1, associated therewith. The number of lamps and associated ballasts in a group varies with the operating characteristics of the dimming ballast. Thus, in an embodiment in which rapid start fluorescent lamps of the type commercially available as F40T12 lamps, were connected with low output dimming ballasts, such as ballasts 6G3670, commercially available from General Electric Company, the lamp group may include from two to twenty lamps, since the full bright lamp current provided by such ballast is considerably below the lamp current provided by a high output dimming ballast, such as commercial ballast 6G5001. In an arrangement using the latter ballast, the lamp groups may comprise from two to twelve lamps without creating an excessive load for the dimming controls.

High power factor ballasts are generally preferred in that the power-correcting capacitors in these ballasts provide additional filtering against transient voltages on the power lines, and thereby provide additional protection against inadvertent triggering of the slave dimming circuits, such as 22, 24.

As shown, each ballast, such as ballast 1 of lamp group A, has a pair of energizing leads 36A, 38A connected to a dimming control circuit, such as 20. A third ballast lead is connected to ground conductor 42. The output of each ballast, such as ballast 1 of lamp group A, is connected over conductors, such as 45, 46; 47, 48 to its associated lamp, such as lamp 1. The left hand terminal of each lamp, such as lamp 1 in lamp group A, is connected over a conductor, such as 40A, to its associated dimming control, such as control 20. As shown, output conductors 36A, 38A, of master dimmer control 20 are connected common to the ballast of lamp group A and conductor 40A is connected common to the lamps of lamp group A.

In the illustrated embodiment, a contactor 18 is energized from source 10 by a master switch 16, and at its contacts (not shown) completes an alternating current circuit over conductors 12 and 14 to the master dimming control 20, and each of the associated slave dimming controls 22, 24, etc. Adjustment of the single intensity selector 26 to different positions adjusts the current output of the master dimming control 20 and slave dimming controls 22, 24 to the lamp group A-Last associated thereat, and thereby effects the adjustment of the lumen output of each of the fluorescent lamps in each of the lamp groups A-Last.

As will be shown, the position or setting of the intensity selector 26 controls the time of conduction of electronic switches in the master dimming control 20 during each half cycle of current, and the lumen output of each lamp in a bank in turn varies directly with the time interval during each half cycle of alternating current that the arc

across each lamp is permitted to persist. The master dimming control 20 includes a pulse derivation circuit which is adjusted to sense the steep current wave front created by the switching of the electronic switches in the master dimming control 20 in the conduction of current to the lamps in its associated lamp group A, and to couple the derived pulse over conductors 32A, 34A to the succeeding slave dimming control 22 in the sequence.

Each slave dimming control circuit, such as 22, includes electronic switches which are controlled by the derived pulse to conduct current to its associated lamp bank. Additionally a pulse derivation circuit in the slave dimming control, such as 22, derives a pulse with operation of such switches for coupling over conductors 32B, 34B to operate the corresponding switches in the succeeding slave dimming control in the sequence.

It will be apparent that the novel system includes building blocks or modules which permit expansion of a system to one of substantially unlimited capacity. Further, since each control circuit or module includes means for deriving a sensing signal to regulate the succeeding control unit there is no limitation in size, such as exists in a system in which the same power signal is used to control each of a large number of dimming devices. It will be additionally apparent that each of the dimming controls, such as 20, 22, 24, may be connected to outlets adjacent the lamp installation, and a single control may yet be used by merely running a pair of wires suitable for Class 1 signal circuit between the successive dimming controls in the system. Obviously, the installation of new lighting systems including dimmer circuits, the modification of systems in existing plants or offices to include dimmer circuits, and the modification of such dimmer system after installation, are considerably simplified.

In addition to these basic features, the resultant control system set forth herein operates in a more satisfactory manner in that the full bright output level is obtainable for each of the lamps with the largest possible dimming range, while yet having a minimum of flickering or "barber-polling" and other undesirable characteristics experienced in many known types of systems. The basic control circuit which is provided to achieve such manner of operation and the manner of its modification to provide master and slave dimming controls having similar structure is now set forth hereat in detail.

Basic dimming control

The basic dimming control 8, as shown in FIGURE 2, is operative to regulate the lumen output of a plurality of fluorescent lamps by varying the time interval that the arc across its associated lamps is allowed to persist during each half cycle of alternating current.

In its most basic form, the dimming control 8 is a package which can be housed in a standard ballast enclosure for mounting within a fluorescent light fixture. The intensity selector for controlling the dimming control is mounted on a strap (not shown) along with a power line switch (not shown) and so designed as to be used in a suitable single gang wall box. Conductors 12 and 14 of the dimming control 8 are connected to the power line switch and conductors 28, 30 of the dimming control 8 are connected to the intensity selector. Output conductors 36, 38 of the dimming control 8 extend to the ballasts for the lamps associated therewith, and conductor 40 is connected to the one end terminal of each of the lamps controlled by the dimmer circuit. In lamp fixture embodiments which include the well-known disconnect lamp-holder socket, conductor 40 is connected to the disconnect lampholder terminal. The identification numerals utilized in FIGURE 2 correspond to those shown in the master slave system of FIGURE 1, and the specific manner of connection of the dimming control 8 to the supply source and associated ballast and lamps will be apparent therefrom.

As shown in FIGURE 2, the dimming control 8 basically consists of a radio frequency interference suppression network 52 connected to input conductors 12, 14 of a 110 volt alternating current source 10, a load resistor network 54 connected to network 52, a phase shift network 56 which is connected to the intensity control conductors 28, 30, and a pair of electronic switches 58, 60 (silicon controlled rectifiers) connected in inverse parallel for selective control by the phase shift network 56 to conduct current over conductors 36, 38 to the associated ballast (not shown).

The radio frequency interference suppression network 52, each of which in one embodiment comprised a winding around a cylindrical core having an inductance of approximately 100 μ h., basically comprises a pair of filter coils 62, 64 connected in the respective sides of the line conductors 12, 14 and a dual capacitor 64A, 64B each section of which may comprise a .02 microfarad, 1500 w.v. D.C. connected respectively between the line conductors 12, 14 and ground conductor 42. A filter 52 provides a degree of isolation for the dimming control from transient electrical noise which may be on the power lines 12, 14, and further suppresses RF noise which may be generated by the very fast switching of the silicon controlled rectifiers 58, 60.

The load resistor network 54 comprises a transformer 66 which in the present embodiment comprises a 120 volt primary and a 200 volt secondary, and a resistor 68 in the order of 5K ohms. The input terminals of the primary winding of transformer 66 are connected to the output conductors of network 52. Lamp conductor 40 is connected to the corresponding input terminal of the primary winding. The output terminals of the load resistor network 54 are connected over conductors 70, 72 to the phase shift network 56 and the silicon controlled rectifiers 58, 60. One output terminal is also connected to one ballast conductor 38 and the other terminal is connected to the second ballast conductor 36. Transformer 66 and resistor 68 are selected to provide an increased voltage across the silicon controlled rectifiers 58, 60 and a fixed minimum load for such rectifiers. The network additionally results in a closer impedance match between the dimming control and the ballasts which are connected thereto over conductors 36, 38 whereby improved dimming performance is provided at the low light intensity levels.

As noted heretofore, the silicon controlled rectifiers 58, 60 are connected across conductors 70, 72 in inverse parallel relation. A capacitor 74 and resistor 80 are connected across conductors 70, 72, the mating terminals thereof being connected to a trigger 82 for silicon controlled rectifier 58. A control bias resistor 84 is connected between the output side of trigger 82 and conductor 70. The common terminal of capacitor 74 and resistor 80 are also connected over conductor 30 to the intensity selector (such as 26—FIGURE 1) and over clamping diode 86 to conductor 70.

The phase shift network 56 for controlling operation of silicon controlled rectifier 60 is similarly arranged, and includes resistance 88 and capacitor 90 connected across conductors 70, 72, the common terminal thereof being connected to the trigger 92 for silicon controlled rectifier 60. Bias resistor 94 for silicon controlled rectifier 60 is connected between the trigger 92 and conductor 72.

The common terminal of capacitor 90 and resistor 88 is also connected over resistor 76 to the intensity control conductor 28 and over clamping diode 78 to conductor 72. In one embodiment, the silicon controlled rectifiers 58, 60 are of the commercially available type with ratings of I_F current=3 a. and PIV=400 volts. Triggers 82, 92 have a V_{BO} =32 volts rating. Bias resistors 84, 94 are 47 ohms, capacitors 74, 90 are .10 microfarad capacitors, resistors 80, 88 are 680K ohms, and resistor 76 is 15K. The clamping diodes have ratings of I_F =400 ma., PIV=200 volts.

In operation, with closure of power to input conductors 12, 14 frequency-suppressed alternating current at a voltage of 200 v. is coupled over conductors 70, 72 to the phase shift networks for rectifiers 58 and 60. At the start of the half cycle in which the voltage across the silicon controlled rectifier 58 is going positive with respect to its cathode, the increasing potential effects a build up of the voltage on capacitor 74, the charge being the result of current flow through capacitor 74 and resistor 80, as well as current flow through the network comprised of diode 78, resistor 76, conductor 28 and the resistance in the intensity selector (such as 26—FIGURE 1), and over conductor 30, it being apparent that the intensity selector 26, resistor 76 and diode 78 are in parallel with resistor 80 in such charging circuit.

As the voltage across capacitor 74 builds up to the forward breakover or threshold voltage of trigger 82, the trigger will switch on and conduct a portion of the charge on capacitor 74 over the gate circuit of silicon controlled rectifier 58 to cause silicon controlled rectifier 58 to conduct for the balance of the half cycle.

It will be apparent that the resistance connected in the parallel control branch for capacitor 74 by the intensity selector, such as 26, will be effective in determining the time interval required for capacitor 74 to reach the threshold value of trigger 82. Variation of the value of the intensity selector resistance is thus used to vary the period of conduction by the rectifier in each cycle and thereby the light output of the lamps controlled thereby.

In the present embodiment, an increase in the resistance in the intensity selector results in a longer charging time for capacitor 74, a greater delay in the half cycle before the occurrence of triggering, and thereby a reduction of the conduction time of the silicon controlled rectifier 58 in such half cycle. Conversely, a decrease in the resistance of the intensity selector results in a shorter charging time for capacitor 74, and conduction of the silicon controlled rectifier 58 at an earlier point in such half cycle.

As the half cycle is terminated, and the potential across the phase shift network 56 is reversed, the silicon controlled rectifier 58 ceases to conduct, and the charging of capacitor 90 is initiated, the charging circuit extending over resistor 88 and capacitor 90, and also over the parallel circuit including resistor 76, conductor 28, intensity selector 26, conductor 30 and rectifier 86 to conductor 70. The charging continues until the voltage on capacitor 90 builds up to the forward breakover voltage of trigger 92, and silicon controlled rectifier 60 is triggered into conduction.

During the period of conduction of rectifiers 58 or 60 in their respective half cycles current is supplied over conductors 36, 38 to energize the associated ballast and lamp in accordance with well known lamp system techniques. Since the intensity selector 26 is connected common to the control circuits for both silicon controlled rectifiers 58, 60, the time interval delay prior to triggering of both rectifiers in the respective half cycles is the same, and as a result a symmetrical current wave is provided to effect improved energization of the fluorescent lamps and ballasts in a dimmer controlled circuit.

The control diodes 86, 88 provide a voltage clamp on the capacitors 74 and 90 respectively, and prevent the capacitors from accumulating an opposite charge when the voltage for their associated silicon controlled rectifiers 58, 60 is in the inverse direction.

It will be apparent that the dimming control is in no way a part of the operating circuit of the ballast which is connected to conductors 36 and 38, and therefore the current to the continuously heated cathodes of the lamps is not effected by the dimming of the lamp except for the slight variation in cathode heating resulting from cathode emission current which is small compared to the total cathode heater current.

The basic arrangement disclosed in FIGURE 2 provides an extremely competent performance in the control of a

ballast and its associated lamps. Of significance is the fact that the novel arrangement is readily adapted by minor modification for use as a master and slave control unit in a dimming system of much larger capacity. Standardization of a single unit for use in these various applications in turn results in reduced manufacturing costs to the benefit of the ultimate user. Such arrangement is now set forth hereat.

Master slave dimming circuits

As indicated above, the novel master-slave dimming control in the present arrangement basically comprises a system in which a basic dimming control (FIGURE 2) is slightly modified to produce a master-dimming control which is capable of commanding a slave (which is in turn a basic dimming control slightly modified) to regulate a subsequent slave of similar structure.

Since both the master and slave components are modified versions of the basic dimmer of FIGURE 2, like component parts in FIGURES 3 and 4 (master and slave, respectively) are identified by like numbers in the succeeding hundred series. With reference to FIGURE 3, for example, it will be seen by comparison of like numbers that the master dimming control circuit 20 differs from the basic circuit of FIGURE 2 by the inclusion of a loosely coupled pulse transformer 192 which includes a primary 196 and a secondary 194 having an inductance of $L_P=10$ mh., $L_S=700$ mh., respectively. The primary winding 196 of transformer 192 is connected in series with the output variable control lead 36A which extends to a ballast for the associated lamp groups. The secondary winding 194 has its end terminals connected to conductors 32A, 34A which extend to the input control circuit for a succeeding one of the slave dimming controls, such as 22 (see FIGURES 1 and 4). The other components of FIGURE 3 are identical to those of FIGURE 2 and the operation of the circuit is identical.

Transformer 192 is very loosely coupled and will accordingly effect the transmission of only the high frequency components of the steep current wave front which is created by the very rapid switching of silicon controlled rectifiers 158, 160. As a result, only very narrow pulses of electrical energy appear in the secondary winding for transmission over conductors 32A, 34A to the succeeding slave dimming control, such as 22, in the system. The magnitude and width of the pulses thus transmitted over such conductors is a function of the load current (which is in turn a function of the number of ballasts and lamps connected to the master dimming control 20). In the described embodiment at least eight ballasts and lamps are connected to the master dimming control 20 to insure the provision of a pulse having sufficient energy to trigger the succeeding slave dimming control throughout its usual dimming range.

As in the basic dimming control unit (FIGURE 2) the setting of intensity selector 26 determines the time of operation of silicon controlled rectifiers 158, 160 in the positive and negative half cycles of current respectively to thereby determine the period in each half cycle that the current is coupled over conductors 36A, 38A to the ballasts for group A which are associated with master dimming control 20. The pulse transformer 192 in turn senses each operation of the silicon controlled rectifiers 158 or 160 in each half cycle, and couples an information or control pulse over conductors 32A, 34A with each such operation to effect the switching of the succeeding slave dimming control, such as 22, in the system.

Slave dimming control circuit

With reference now to FIGURE 4, each slave dimming control circuit, such as 22, is similar to the basic dimming control of FIGURE 2 and the master dimming control 20 of FIGURE 3, and has like components identified by the "200" series.

In the slave dimming control 22, the input control conductors 32A, 34A comprise the pulse output conductors 32A, 34A of the master dimming control 20. In subsequent slave units the input conductors, such as 32A, 34A, are connected to the output conductor of the pulse derivation circuit of a preceding slave dimming control in the sequence. The input conductors 32A, 34A are connected to the input terminals of a four diode bridge network 300, including diodes 301, 302, 303, 304, respectively which may be conventional diodes having commercial ratings of $I_F=400$ ma., $PIV=200$ volts. The input pulses are polarized and extended over the output terminals of the bridge rectifier 300, a shaping network including capacitor 305, diode 306 and the inductance of the primary 308 of transformer 307. Capacitor 305, in one embodiment, is in the order of .02 μ f. and diode 306 is a zener diode, $V_Z=8$ volts. In transformer 307 $L_P=700$ mh., $L_S=900$ mh. The two section secondary 309, 310 of transformer 307 is connected to the gates for the silicon controlled rectifiers 258, 260 respectively. The remainder of the circuit is identical to the master dimming control circuit 20 (FIGURE 3).

With the coupling of a pulse from the master dimming control 20 over conductors 32A, 34A to the rectifier 300 in the slave dimming control 22, the bridge 300 effects the provision of a triggering pulse to the gate circuit for each of the silicon controlled rectifiers 258 and 260 in each half cycle. However, in accordance with the particular half cycle of the alternating current which is coupled over conductors 12A, 14A only one of the rectifiers operates in response thereto. With the operation of the effective one of the silicon controlled rectifiers 258, 260, the resultant steep current wave front created by the switching thereof is sensed by the primary winding 296 of transformer 292 and a narrow command pulse is transmitted over conductors 32B, 34B to the succeeding slave dimming control in the system (see FIGURE 1). With the operation of the effective one of the silicon controlled rectifiers, such as 258 in a half cycle, current is coupled over conductors 36B, 38B to the ballasts for the lamps in the associated lamp group B, and the lamps are conductive for the remaining portion of the half cycle.

The output leads 32 Last, 34 Last on the last slave dimming control circuit of the system (circuit 24 in FIGURE 1) are connected together with an insulating solderless connector so that the units may be sold as like models without designating the circuit of the units as necessarily being installed as the last unit in the system. The power in the leads of the last unit is limited due to the loose coupling of the output transformer, such as 292, and the shorting of the leads in this manner has no harmful effect.

In the illustrated embodiment of FIGURE 1, a single intensity selector 26 is used to control the light intensity output of the lamps in the system. In the event that the light intensity output of the system is to be controlled at more than one location, a latching relay is connected between the intensity selectors in such manner as to selectively insert only one of the several intensity selectors, such as 26, in the circuit including conductors 28, 30 at any time. Such arrangement provides for increased flexibility in installation.

In that the latching relays are operative with a low voltage source, such arrangement may be included in a system at a minimum of installation cost. In larger installations in which several branch circuits are required, it is desirable that the circuits be supplied from the same transformer secondary, and that the load be equally divided between the circuits. In such arrangement, load switching is normally accomplished by a magnetic contactor 18, as shown in FIGURE 1, whereby a single switch 16 (usually located adjacent to the intensity selector 26 at the wall control location) can be used to control a large number of branch circuits.

The novel electronic dimming system described hereinbefore makes possible the control of small and large

lamp installations throughout a larger dimming range with more stability and in a more economical manner. Further, the component circuitry is such that the units may be housed in basic module packages which permits a further reduction in overall cost from a manufacturing and installation standpoint.

In addition to providing dimming control for fluorescent lamps, the novel system disclosed herein may also be utilized as a dimmer control for incandescent lamps, as a motor control circuit, and for other similar types of applications. In the use of the basic dimming control circuit for incandescent lamps, the cost is materially reduced in that certain components, such as the impedance matching transformer and dummy resistor load, are not required. Slight modification of the RF section consistent with conventional practice would be in order.

Although only certain particular embodiments of the invention have been shown and described, it is apparent that modifications and alterations may be made therein, and it is intended in the appended claims to cover all such modifications and alterations as may fall within the true spirit and scope of the invention.

What is claimed is:

1. A dimming system for controlling the lumen output of a plurality of lamp banks energized from a source of undulating current comprising a master dimming circuit for a first bank of lamps including input means for connecting said master dimming circuit to said source, switch means operative between different conditions of operation to intermittently conduct current to said first bank of lamps during a cycle of said undulating current, control means for adjusting the period of conduction of said switch means in a cycle to different values, and pulse derivation means connected to sense operation of said switch means in the supply of power from said source to said first bank of lamps, including means for deriving a pulse of short duration relative to the period of conduction by said switch means only responsive to a switching operation by said switch means, and at least one slave dimming circuit for controlling a second bank of lamps including further switch means connected to extend power to said second bank of lamps and means connected to said pulse derivation means for operating said further switch means for a period similar to that of the switch means in said master circuit in response to receipt of said short duration pulse from said pulse derivation means.

2. A dimming system for controlling the lumen output of a plurality of lamp banks energized from a source of undulating current comprising a master dimming circuit for a first bank of lamps including input means for connecting said master dimming circuit to said source, switch means operative to intermittently conduct current to said first bank of lamps during a cycle of said current, and means for adjusting the period of operation of said switches in a cycle to different values; a plurality of slave dimming circuits, each of which includes switch means for controlling the lumen output of a different bank of lamps, and pulse responsive means for controlling energization of said switch means; pulse derivation means in each dimming circuit for providing a pulse of electrical energy only responsive to a switching operation by its associated switch means, means for connecting the pulse responsive means of one slave dimming circuit for control by the pulse output of said master dimming circuit, and means for connecting the pulse responsive means of each succeeding slave dimming circuit in the system for control by the pulse output of the derivation means in a preceding slave dimming circuit.

3. In a dimming system for controlling the lumen output of a plurality of lamp banks energized from a source of undulating current voltage comprising a first dimming circuit for a first bank of lamps including input means for connecting said dimming circuit to said voltage source, at least one electronic switch, control means for

providing control voltages to operate said electronic switch during at least a partial interval of one-half cycle of said undulating current including intensity selector means for varying the starting time of said interval, output means for coupling current to said first bank of lamps during said interval of switch operation, and pulse derivation means for providing a pulse of short duration relative to said period of operation of said switch only responsive to operation by said switch to conduct power to said first bank of lamps, and at least one slave dimming circuit for controlling a second bank of lamps including further switch means in said slave dimming circuit connected to extend power to said second bank of lamps, and means connected to said pulse derivation means for operating said further switch means for a period similar to that of said one switch in response to receipt of said short duration pulse from said pulse derivation means.

4. In a dimming system as set forth in claim 3 in which said input means includes a radio frequency filter for suppressing radio frequency noise generated by switching of said electronic switch.

5. In a dimming system as set forth in claim 3 in which said lamp banks include ballast means, and in which said input means include a load matching network including a transformer and a load resistor network connected to match the impedance of said first dimming control with the impedance of the ballasts in said first lamp bank.

6. In a dimming system as set forth in claim 3 in which said first lamp bank includes ballast means, and in which said output means in said dimmer circuit includes a lead for connection to said ballast means, and means connecting said electronic switch in series with said lead for said ballast means.

7. In a dimming system as set forth in claim 3 in which said control means for said electronic switch includes a phase shift network including capacitor means, means for charging said capacitor responsive to initiation of a half cycle of said undulating current, and means for operating said electronic switch responsive to build-up of a charge on said capacitor to a predetermined value.

8. In a dimming system as set forth in claim 3 in which said control means for said electronic switch includes a phase shift network including capacitor means, means for charging said capacitor responsive to initiation of a half cycle of said undulating current, and means for operating said electronic switch responsive to build-up of a charge on said capacitor to a predetermined value, and in which said intensity selector means comprises adjustable resistor means connected to adjust the current flow in said charging circuit for said capacitor to different values.

9. In a dimming system as set forth in claim 3 in which said control means for said electronic switch includes a phase shift network including capacitor means, means for charging said capacitor responsive to initiation of a half cycle of said undulating current, means for operating said electronic switch responsive to build-up of a charge on said capacitor to a predetermined value, and clamping means connected across said capacitor to prevent said capacitor from accumulating a charge during the succeeding half cycle.

10. In a dimming circuit as set forth in claim 3 which includes a second electronic switch, and in which said control means include means for operating said switches for corresponding intervals in different half cycles and said pulse derivation means includes means connected to sense the high frequency components of the steep current wave front which occurs responsive to each operation of said switches, and means for providing one of said short duration pulses for each of said sensings.

11. In a dimming system for controlling the lumen output of a plurality of lamp banks energized from a source of undulating current voltage comprising a first dimming circuit for a first bank of lamps including input

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means for connecting said dimming circuit to said source, at least one electronic switch, control means for providing control voltages to operate said electronic switch during at least a partial interval of one-half cycle of said undulating current including intensity selector means for varying the starting time of said interval, output means for coupling current to said first bank of lamps during said interval of switch operation, and pulse derivation means for providing a pulse of electrical energy only responsive to operation of said switch comprising a loosely coupled pulse transformer having a primary winding, means connecting said primary winding to sense the high frequency components of the steep current wave front which occur responsive to operation of said switch, and a secondary winding including output conductors for providing a narrow pulse of electrical energy to a further dimmer device in said system.

12. In a dimming system for controlling the lumen output of lamps energized from a source of undulating current voltage comprising a dimming circuit for a bank of lamps including a first input means for connecting said dimming circuit to said voltage source, at least one electronic switch, control means for providing control voltages to operate said electronic switch during at least a partial interval of one half cycle of said undulating current including a second input means over which a control pulse is received during said half cycle for a period relatively shorter than said partial interval, pulse responsive means for controlling said switch to conduct in response to receipt of said control pulse over said second input means including a rectifier circuit connected to said second input means to polarize said received pulses, a pulse shaping circuit connected to said rectifier circuit to shape said polarized pulses, and means for coupling the shaped pulse output of said pulse shaping circuit to said electronic switch, and output means for coupling current to said lamps from a voltage source during conduction by said switch from the time of receipt of said control pulse to the end of the half cycle in which the short pulse was received.

13. A dimming system as set forth in claim 12 which includes a signal output means, and pulse derivation means for providing a pulse over said signal output means only responsive to operation of said switch.

14. A dimming system as set forth in claim 12 which

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includes a plurality of said dimming circuits, each of which includes a pulse derivation circuit, and in which said input control means in each dimmer circuit is connected to the output of a pulse derivation circuit of another one of said dimmer circuits.

15. A dimming system for controlling the lumen output of a plurality of lamp banks energized from a source of alternating current comprising a master dimming circuit for a first bank of lamps including input means for connecting said master dimmer circuit to said source, a first and a second electronic switch means including a phase shift network for providing control voltages to operate at least one of said electronic switches during an interval of one-half cycle of said alternating current, intensity selector means for varying the duration of said interval, output means for coupling current to said first bank of lamps during said interval of operation of said switches, and pulse derivation means for providing a pulse of electrical energy in response to each switching operation by one of said switches; and a slave dimming circuit for controlling a second bank of lamps including control means responsive to said pulse from said pulse derivation means to operate said second bank of lamps for a period corresponding to the period of operation of said first bank of lamps, including pulse-responsive means, means connecting said pulse responsive means to the pulse derivation means of said master dimming circuit, further switches connected for selective operation by said pulse responsive means, output means for coupling current to the second lamp bank responsive to energization of said further switches, and pulse derivation means for coupling a pulse to a further slave dimming circuit responsive to operation of one of said further switches.

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