March 10, 1970 S. L. ROSS ET AL 3,500,455

LIGHT RESPONSIVE ELECTRICAL LAMP DIMMING MEANS

Filed July 5, 1968 2 Sheets-Sheet 1

FIG. 1

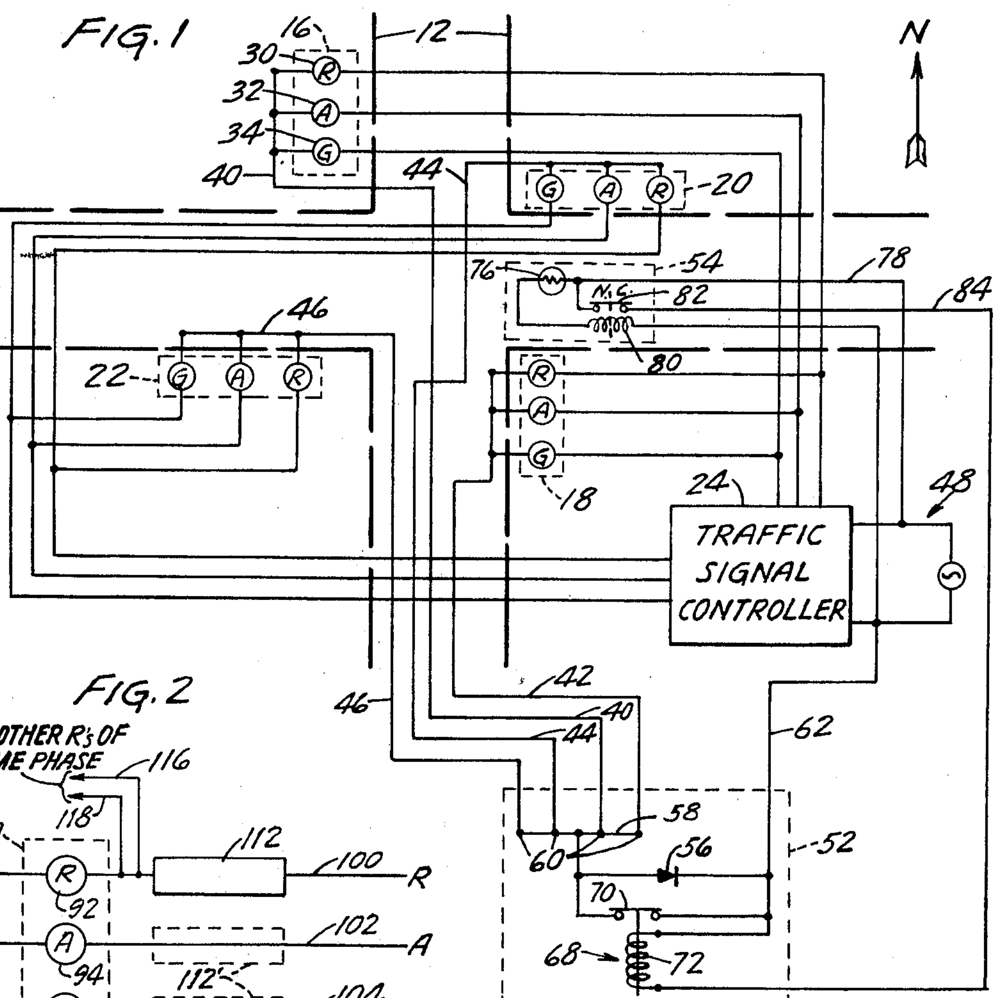


FIG. 2

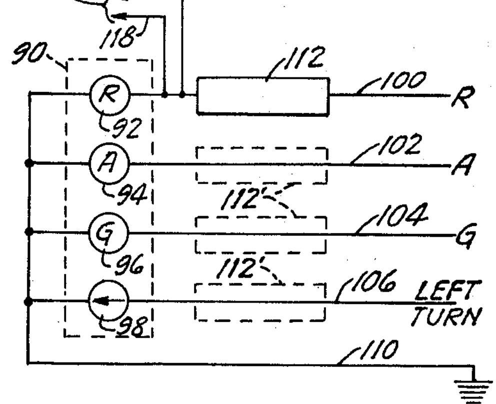


FIG. 3

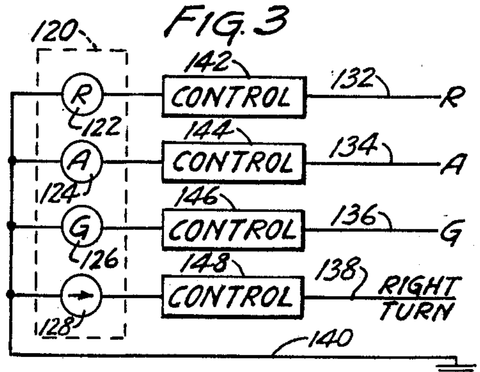
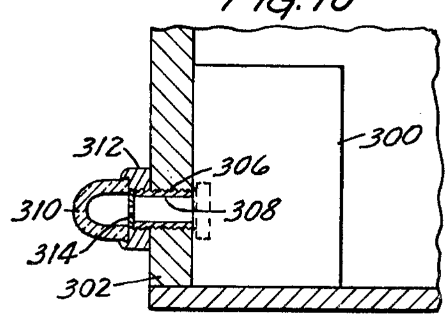


FIG. 10



INVENTORS
STANLEY L. ROSS
JOSEPH T. FITZPATRICK
BY Kinney, Alexander,
Sell, Steldt & DeLaHunt
ATTORNEYS

LIGHT RESPONSIVE ELECTRICAL LAMP DIMMING MEANS

Filed July 5, 1968 2 Sheets-Sheet 2

FIG. 4

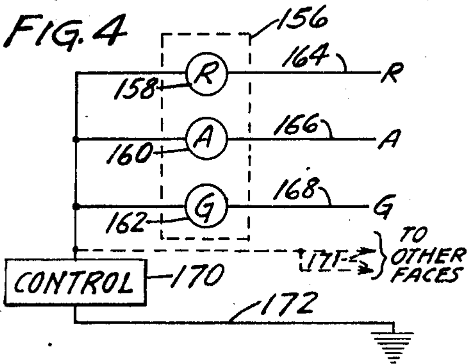


FIG. 5

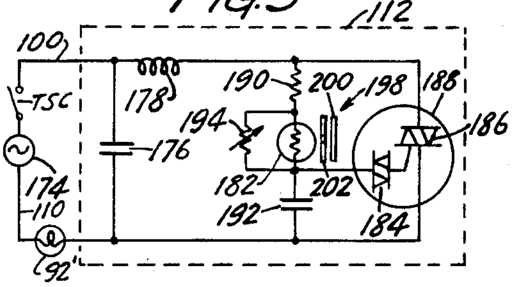


FIG. 7

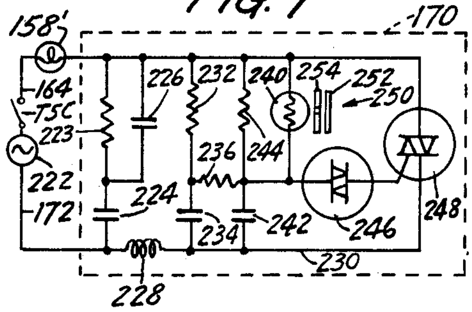


FIG. 6

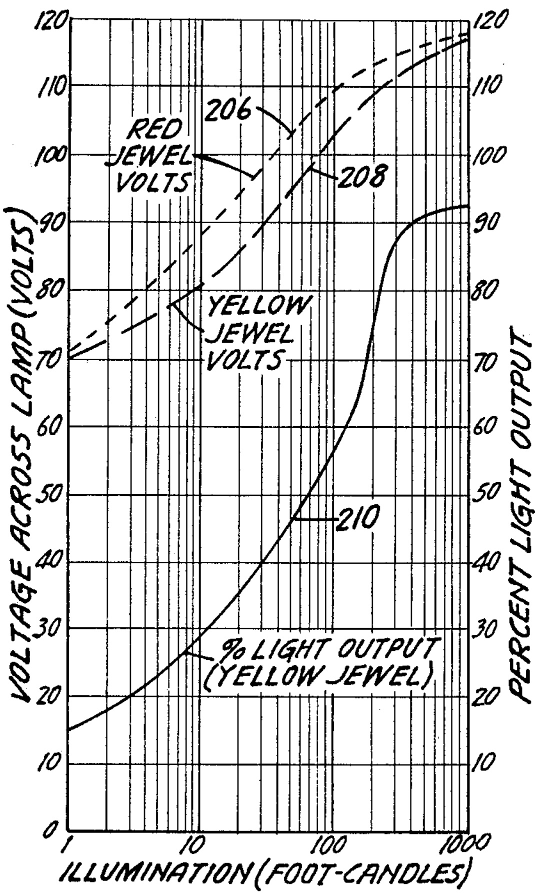


FIG. 8

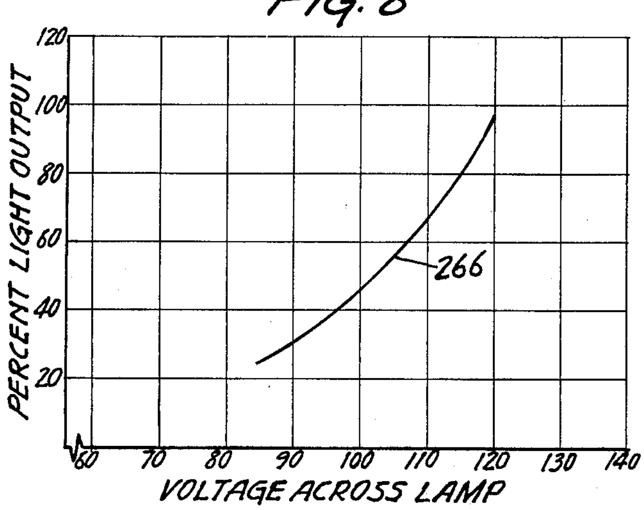
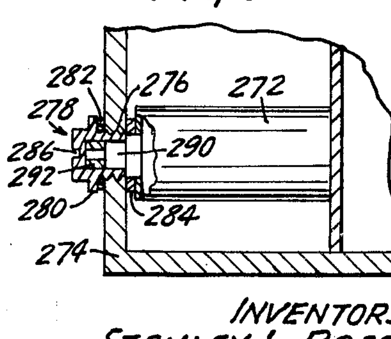


FIG. 9



INVENTORS
STANLEY L. ROSS
JOSEPH T. FITZPATRICK
BY Kinney, Alexander, Sell, Steldt & De La Hunt
ATTORNEYS

United States Patent Office

3,500,455
Patented Mar. 10, 1970

3,500,455
LIGHT RESPONSIVE ELECTRICAL LAMP DIMMING MEANS

Stanley L. Ross, Gem Lake, and Joseph T. Fitzpatrick, North Oaks, Minn., assignors to Minnesota Mining & Manufacturing Company, St. Paul, Minn., a corporation of Delaware

Filed July 5, 1968, Ser. No. 742,627
Int. Cl. H05b *37/02, 39/04, 41/36*
U.S. Cl. 315—149 22 Claims

ABSTRACT OF THE DISCLOSURE

A light responsive electrical lamp dimming means is shown which is adapted for use with an alternating current voltage source energized traffic control system and wherein the dimming means proportionally varies intensity of a traffic signal lamp between a high intensity level and a predetermined low intensity level as a function of sensed background illumination. In one embodiment, a light responsive electrical lamp dimming means includes a controllable bi-directional conducting means which is controlled by a triggering means which in turn is responsive to a background illumination sensing means adapted to detect changes in background illumination in the vicinity of a lamp for controlling the triggering means which varies conduction of the bi-directional conducting means between a first state and a second state in proportion to sensed changes in background illumination between a bright level to a preselected dark level.

Electrical lamp dimming circuits which selectively switch a rectifier into and out of a circuit for changing the intensity of a lamp are known; see for example, Patent Nos. 2,896,125; 3,009,071; 3,028,525 and 3,037,146. In such electrical lamp dimming circuits, the rectifier, when connected into the energizing circuit, causes the lamp to operate at a preselected minimum intensity level. When the rectifier is selectively switched out of the circuit, the lamp is permitted to be energized by the energizing circuit at a normal intensity. Thus, by manually switching the rectifier into and out of the energizing circuit, the lamp intensity is abruptly changed between one of two discrete intensity levels.

The electrical lamp switching mechanism disclosed in Patent No. 2,896,125 is typical. In Patent No. 2,896,125, a bypass circuit is connected in parallel to the rectifier. The bypass circuit includes a switching mechanism having a switching member which, when manually connected in parallel to the rectifier, enables the energizing circuit to apply normal voltage to the lamp thereby operating the lamp at a normal intensity level. When the switching member is manually switched to an open-circuit position, the rectifier is rendered conductive for approximately one-half of an alternating current voltage cycle. The power applied to the lamp is approximately one-half of its original value and the lamp is then abruptly dimmed to a lower intensity level which is equal to about 25 to 30 percent of the normal intensity level when the lamp is operated at normal voltage.

Another known system for selectively dimming the lumen output of an electrical lamp is shown in Patent No. 3,061,744. The lamp dimming circuit utilizes a four-layer diode, such as a Zener diode, in combination with a half-wave rectifier connected in a back-to-back relationship. Such a combination permits manual control of the voltage applied to a lamp such that the lumen output thereof can be selectively varied from substantially zero percent to 100 percent.

In addition to the above, Patent No. 3,061,744 also

discloses circuitry for triggering the gate of a silicon-controlled rectifier (SCR). Also, this circuitry includes switching means for selectively switching a diode into and out of parallel relationship with the silicon-controlled rectifier in order to dim the lumen output of the lamp over a range of between zero and 100 percent.

Use of SCR's as a continuously variable dimmer switch for controlling the intensity level of a lamp at a manually-set intensity level is disclosed in U.S. Patent Nos. Re. 26,119 and 3,103,618. For example, in Patent No. 3,103,618, a variable phase shift circuit is used to provide a controllable gating signal for the gate electrode of the SCR in response to a manual setting of a variable resistor in the phase control circuit.

Light responsive switching circuits for selectively energizing and de-energizing a lamp as a function of ambient light illumination are known in the art. For example, in Patent Nos. 3,088,051 and 3,210,611, a light responsive element is used to control actuation of a relay by means of a transistor switching circuit for selectively energizing a lamp. In the circuits in each of the Patent Nos. 3,088,051 and 3,210,611, the lamps are abruptly switched between two different levels of illumination; namely, substantially 100 percent lumen output when the lamps are energized and zero percent lumen output when the lamps are de-energized.

Use of photocells, as bistable switching devices, in combination with triggering circuits for controlling phase angle of conduction of a bidirectional gated semiconductor device, such as a triac are known. For example, the circuit of FIGURE 19 appearing at page 12 in G.E. "Application Note" Number 200.35 dated March 1966 discloses use of a photocell as part of a firing circuit for a unijunction transistor which in turn triggers a triac which also is controlled by a small pilot SCR which gives continuous drive to the gate following triggering of the triac until the current load is high enough for the triac to latch. In this circuit of FIGURE 19, the photocell is merely utilized as a bisable control device having a finite switching time.

Also, FIGURES 24 and 25 on page 15 of the same G.E. "Application Note" cited above utilize a photocell as a bistable switch for controlling triggering of a triac. In each of the above uses of photocells in the triggering circuits, an extremely small change in foot-candle illumination, say in the order of 2 foot-candles or so, causes the photocell to abruptly change from a high resistance (dark level) to a low resistance in the order of 2000 ohms when the photocell is illuminated. Thus, the abrupt switching characteristic of the photocell bistable control device is abruptly responsive to the illumination directly incident upon the photocell and is therefore not capable of being used to proportionally control triggering of the triac over a wide range of illumination.

One primary disadvantage of the prior art devices, including those discussed hereinabove, resides in that a light sensing means heretofore has been used for selectively actuating and deactuating a lamp in response to ambient illumination levels in the vicinity of the light sensing means. Further, the electrical lamp dimming circuits of the prior art, including those cited above, can be selectively controlled only in response to a manual setting of a dial or its equivalent.

The present invention overcomes the disadvantage of the prior art devices, including those set forth above, by a unique light responsive electrical lamp dimming system and means which proportionally controls the intensity of a lamp between a high intensity level and a predetermined low intensity level as a function of background illumination in the vicinity of the lamp.

The prior art devices which utilize a light sensing means have apparently neither recognized the advantage of nor solved the problem of selectively controlling lamp intensity in proportion to background illumination. In the embodiment disclosed herein, the background illumination which impinges on the light sensing means, such as, for example, a photocell, is selectively transmitted so as to vary the light sensing means characteristics in proportion to the background illumination.

In addition to the above teachings, the present invention also teaches that the proportional dimming characteristics of the light responsive electrical lamp dimming circuit can be preset such that when the background illumination decreases below a preselected dark level, the intensity of the controlled lamp can be fixed at a predetermined low intensity level.

One important use of a light responsive electrical lamp dimming means of the present invention is in a traffic control system. One problem encountered by traffic control engineers in designing traffic signal systems is to match the intensity level or lumen output of a traffic signal lamp at a level which is compatible with the background illumination at an intersection served by the traffic lighting system. For example, around sunset on a relatively clear day, a driver travelling in a westerly direction normally has the sun directly in his eyes. When a driver travelling in a westerly direction on such a day approaches a traffic signal section having a setting sun directly therebehind as the background illumination, he may not be able to distinguish which traffic indication is being displayed by the traffic signal lamp servicing the lane in which he is travelling. One reason why a driver cannot sometimes distinguish the signal condition for his lane is that the traffic signal lamp has an intensity level which is equal to or lower than the intensity level of background illumination; namely, the setting sun.

One way of solving a problem presented by a setting sun as described above is to utilize a traffic signal lamp having a high intensity or lumen output. This would require increasing the intensity level of the lamp such that it is substantially brighter relative to the background illumination, e.g. the setting sun, than the intensity level of the lamp when the background illumination is dark. After the sun has set, the background illumination is substantially reduced in level. The background illumination may be a dark sky or could be derived from artificial lighting, such as for example fluorescent signs, overhead street lights and the like. In either case, if the traffic signal lamp intensity was increased so as to be brighter to compensate for the background illumination including the setting sun, the lamp would be extremely bright in a dark background illumination. A driver approaching an intersection under such a condition could be blinded by the bright or high intensity traffic signal lamp.

The advantages and desirability of controlling the intensity of the traffic signal lamp such that its intensity is at a high level when the background illumination in the vicinity of the lamp is at a bright level and its intensity is at a lower level when the background illumination is at a lower level is readily apparent.

Many attempts have been made, without a great deal of success, to match or correlate the intensity of a traffic signal lamp with its associated background illumination. At intersections where the sky and other background illumination are at a relatively normal level during the day and are at a dark level after sunset, traffic signal lamps are used which have a wattage rating less than that required by traffic highway standards. A lower wattage traffic signal lamp having a dark background illumination is not apt to blind a motorist travelling in a vehicle toward the intersection being serviced by the traffic signalling system.

Another prior art solution to this problem has been to utilize a transformer having a normal voltage winding and a separate bucking winding for supplying voltages to the traffic signal lamp. When a reduced voltage is required, the bucking winding is energized which in turn generates an opposite magnetic field which results in a reduced voltage being applied to the traffic signal lamps. The reduced voltage, in turn, operates the lamps at a reduced intensity level. Use of transformers with separate bucking windings results in a traffic signal light dimming circuit having several disadvantages, such as for example being relatively expensive, being limited in range of control, being bulky and heavy and being difficult to install in existing traffic signal intersections.

One advantage of the present invention is that a unique and relatively inexpensive light responsive electrical lamp dimming means is provided which is capable of selectively varying the intensity of a single traffic signal in a traffic signal face. The intensity of the traffic signal lamp can be varied between a high intensity level and a predetermined low intensity level in proportion to the background illumination varying between a bright level and a preselected dark level.

Another advantage of the present invention is that the light responsive electrical lamp dimming means can be utilized to proportionally control the intensity of (a) a single traffic signal lamp or indication in a selected traffic signal face, (b) the traffic signal lamps or indications which are identical and in the same phase wherein each lamp is located in a different traffic signal face, (c) the traffic signal lamps or indications in a single traffic signal face, or (d) the traffic signal lamps or indications in a plurality of traffic signal faces in the same phase.

Another advantage of the present invention is that side glow can be effectively reduced and controlled from a display device adapted for use as a traffic signal section. One such display device includes a condensing display lens defining a viewing surface, lighting means for providing modifiable diffuse illumination of the lens from points substantially at the focus of the lens and aperture means disposed substantially at the focus which outlines a predetermined viewing area, such as for example a selected traffic lane, as described in a copending patent application of Roger H. Appledorn, Ser. No. 571,639, having a common assignee. Normally, such side glow is a function of the intensity of the traffic signal lamp and is most noticeable when the traffic signal lamp intensity is substantially greater than the intensity of the background illumination. Thus, dimming of the traffic signal lamp is in proportion to the sensed background illumination is effective to reduce and control such side glow.

An other important use of the light responsive electrical lamp dimming means of the present invention is that the intensity of the traffic signal lamps in traffic signal faces of different phases, but which are facing in a preselected direction, can be selectively dimmed. For example, during the sunset conditions described above, a motorist travelling eastbound with the sun behind him would encounter a low level background illumination such that a bright or high intensity traffic signal lamp would be blinding to the motorist.

On the other hand, a motorist travelling westbound would encounter a bright level background illumination; namely, a setting sun. In this instance, it is desirable to have the traffic signal lamps, which control the traffic moving in a westerly direction, at a high intensity level. By use of the present invention, each of the traffic signal lamps controlling the traffic moving eastbound can be operated at a lower intensity level while each of the traffic signal lamps controlling the traffic moving westbound can be operated at a high intensity level.

Another advantage of the present invention is that the intensity of any single traffic signal lamp or all of the traffic signal lamps in a given traffic signal face or faces can be separately controlled for other unusual background conditions. For example, a given traffic signal lamp may have a low level background illumination during daylight hours such that the intensity of the traffic signal lamp should be at an intensity level which is less than normal. The same traffic signal lamp, or traffic signal face or faces as the case may be, could well have a background illumination which is at a brighter level during nighttime hours than daytime hours. Such a brighter background illumination level could be due to artificial street lighting, neon signs and the like. In this instance, the intensity of the traffic signal lamp in the face or faces would then be increased in intensity to compensate for the brighter background illumination.

These and other advantages of the present invention will become apparent when considered in light of the description of several embodiments set forth herein taken together with the drawing wherein:

FIGURE 1 is a diagrammatic representation, partially in block form and including a schematic diagram, illustrating a light responsive electrical lamp dimming system adapted for use in a traffic signal system for controlling an intersection;

FIGURE 2 is a schematic diagram partially in block form illustrating a traffic signal face including a left turn indication wherein only the red indication in a single traffic signal face or identical indications of the same phase in other traffic signal faces is controlled by a light responsive dimming means of the present invention;

FIGURE 3 is a schematic diagram partially in block form illustrating a traffic signal face including a right turn indication wherein each individual indication is controlled by a light responsive light dimming means of the present invention;

FIGURE 4 is a schematic diagram of a traffic signal section wherein all indications in all traffic signal faces of the same phase are controlled by a light responsive light dimming means of the present invention;

FIGURE 5 is a schematic diagram of one embodiment of a circuit capable of use in FIGURES 2 and 3;

FIGURE 6 is a graph illustrating the percentage light output plotted as a function of illumination of the lamp of FIGURE 5 wherein a yellow jewel is used as a light absorbing means and wherein the alternating current voltage applied to the lamp of FIGURE 5 is plotted as a function of illumination for the yellow jewel and a red jewel;

FIGURE 7 is a schematic diagram of yet a different embodiment of the present invention which is capable of use in FIGURE 4;

FIGURE 8 is a graph of the percent light output plotted as a function of voltage across the lamp for the circuit of FIGURE 7;

FIGURE 9 is a fragmentary side cross-sectional view of a traffic signal section housing having mounted therein a packaged electrical circuit illustrated in FIGURE 5; and

FIGURE 10, which is located on the first sheet of drawing, is a fragmentary side cross-sectional view of a traffic signal section housing having mounted therein a packaged electrical circuit illustrated in FIGURE 7.

Briefly, this invention relates to a light responsive electrical lamp dimming circuit, system and means adapted to be energized from a source of alternating current for proportionally controlling of a lamp between a high intensity level and a predetermined low intensity level as a function of sensed background illumination. In addition, the electrical lamp dimming means can be used in a traffic signal control system for proportionally operating a traffic signal lamp over a range of desired operating levels of illumination.

In one embodiment, the light responsive electrical lamp dimming means includes a controllable bi-directional conducting means which is connected in series with the lamp to be dimmed for controlling conduction of an alternating current through the lamp. The amplitude of the voltage applied across the lamp is dependent on the voltage magnitude of the alternating current source at the time the bi-directional conducting means is rendered conductive. A triggering means is electrically connected to the bi-directional conducting means and selectively varies conduction thereof between a first state wherein an electrical current is passed through the lamp to establish a voltage thereacross for substantially an entire portion of an alternating current voltage cycle which operates the lamp at a high intensity level and a second state wherein an electrical current is passed through the lamp to establish a voltage thereacross for at least a portion of an alternating current voltage cycle which operates the lamp at the predetermined low intensity level. A background illumination sensing means, which is adapted to detect changes in background illumination in the vicinity of the lamp, is capable of controlling the triggering means for varying conduction of the bi-directional conducting means between the first state and the second state in proportion to sensed changes in background illumination which varies from a bright level to a preselected dark level.

FIGURE 1 illustrates diagrammatically a typical intersection of two highways, generally designated by dashed lines **12** and **14**, which are serviced by a traffic signal system. The traffic signalling system illustrated herein for purposes of example comprises four traffic signal faces designated **16**, **18**, **20**, **22** and a traffic signal controller **24**. The traffic signal controller **24** is electrically connected to and controls each of the traffic signal faces **16–22** in a normal manner. Each traffic signal face is illustrated to contain three indications, generally known as red, amber and green. Normally, an incandescent traffic signal lamp and an appropriate colored lens is utilized to establish the color for the indication. In addition, of a mark, such as an arrow to indicate direction, is required, the colored lens is appropriately masked. In traffic signal face **16**, the red indication is generally designated as lamp **30**, the amber indication is designated as lamp **32** and the green indication is designated as lamp **34**. Each of the other faces **18–22** has a similar red indication, amber indication and green indication.

In the intersection formed by crossing of highways **12** and **14**, the north-south lanes are controlled by traffic signal faces **16** and **18**. Traffic signal face **16** may be located in the northwest corner of the intersection while traffic signal face **18** may be located in the southeast corner of the intersection. The placement of the traffic signal faces of FIGURE 1 is merely exemplary and it is contemplated that the traffic signal faces could well be located in other corners of the intersection in accordance with existing traffic signal standards. Typically, traffic signal face **16** located in the northwest corner of the intersection would be used for controlling traffic in the northbound lane of highway **12** while traffic signal face **18** would be used to control traffic in the southbound lane of highway **12**.

Control of traffic flow along one street or highway is generally referred to as traffic movement. The term "phase" refers to the group of indications used for controlling traffic movement in a programmed sequence. The sequence of traffic movement is the programmed order in which traffic flow through the intersection is controlled, such as, for example, that vehicles are given the right-of-way to proceed in a given direction, e.g. green indication; are required to stop, e.g. red indication; or are warned of a change in traffic movement, e.g. amber indication. In FIGURE 1, one phase, which includes traffic signal faces **16** and **18**, controls the traffic movement in both the northbound and southbound directions of highway **12** and a second phase, which includes traffic signal faces **20** and **22**, controls the traffic movement in both the eastbound and westbound directions of highway **14**. Thus, in FIGURE 1, traffic movement through the intersection is controlled in two phases.

In some intersections, traffic movement is controlled by lanes or directions thereby requiring phases for each lane or direction. For example, in FIGURE 1 (not shown), traffic signal faces **16** and **18** and **20** and **22** could be controlled by separate phases such that traffic movement is controlled in four phases.

For purpose of consistency, the use of the terms "traffic signal section," "indication," "indicators" or "color" refers to a traffic signal lamp in combination with a colored lens to form a single light unit which together with other units form a traffic signal face. In FIGURE 1, this corresponds to the red indication **30** which together with amber indication **32** and green indication **34** forms the traffic signal face **16**. Traffic signal faces **16** and **18** form a single phase as illustrated in FIGURE 1. Thus, the red indications in the traffic signal faces **16** and **18** are identical indications in the same phase wherein each section is located in a different traffic signal face.

Use of the term "traffic signal lamps or indicators in a plurality of traffic signal faces in the same phase" includes the indicators used in the same phase for controlling traffic movement. For example, in FIGURE 1, this includes the red, amber and green indications of traffic signal faces **16** and **18**.

In addition, the term "traffic signal lamps or indications in a single traffic signal face" includes one or more indication used in a standard traffic signal face. For example, in FIGURE 1, this includes red indication **30**, amber indication **32** and green indication **34** in traffic signal face **16**.

Traffic signal face **20** is illustrated to be located in the northeast corner of the intersection and is adapted to control the eastbound traffic of highway **14**. The traffic signal face **22** is illustrated herein in the southwest corner of the intersection and is adapted to control the westbound lane of highway **14**.

In some installations, it would be possible to install more than one traffic signal face at a given corner of the intersection. For example, the traffic signal face **16** which controls the northbound lane of highway **12** could also have mounted on the same pole in a parallel aligned relationship a traffic signal face (not shown) which is identical to traffic signal face **18** and which would also be used as a second parallel control for the southbound lane of highway **12**. A combination of one or more faces in a mountable assembly is generally referred to as a "traffic signal head" or "head." Additionally, other lane control signals or indications could be added to or be a traffic signal face, for example, controlled left and right turn indications, pedestrian control indications and the like.

Traffic signal faces **16** and **18** serving the northbound and southbound lanes of highway **12** respectively are electrically connected to the traffic signal controller **24** such that all of the red indications, amber indications and green indications would be energized in proper sequence. Similarly, traffic signal faces **20** and **22** would be electrically connected to traffic signal controller **24** in the manner such that the red indication, amber indication and green indication thereof would be energized in proper sequence.

One possible electrical connecting diagram is illustrated in FIGURE 1 for accomplishing the appropriate interconnecion between traffic signal faces **16–22** and traffic signal controller **24**. This electrical diagram is believed to be adequately shown by FIGURE 1 and need not be considered in detail here.

Each of the traffic signal faces **16–22** is illustrated as having a return or neutral of each indication electrically connected to a common neutral. For example, traffic signal face **16** has the neutrals of its traffic signal lamps in the red indication, amber indication and green indication electrically connected to a common neutral **40**. Traffic signal face **18** has the neutrals of all of its traffic signal lamps of each indication electrically connected to a common neutral **42**. Traffic signal face **20** has the neutrals of its traffic signal lamps in each of the indications electrically connected to a common neutral **44**. Similarly, traffic signal face **22** has the neutrals of its traffic signal lamps in each of the indications electrically connected to a common neutral **46**. The traffic signal controller **24** is electrically connected to and energized from an electrical distribution system, which is generally designated as **48**, which may be a 120 volt, 60 cycle, alternating current voltage having a system ground.

Each of the common neutrals **40–46** for traffic signal faces **16–22** respectively is electrically connected to a traffic control system having a control means, generally designated as **52**, and a light sensing means, generally designated as **54**. The control means **52** includes a unilaterally conducting means such as, for example, a diode **56** having its anode electrically connected to a common neutral bus bar **58**. The common neutral bus bar **58** has connecting terminals, generally designated as **60**. The connecting terminals **60** have common neutrals **40–60** electrically connected thereto. The cathode of diode **56** is electrically connected via a common neutral **62** back to the system ground of the electrical distribution system **48**. The unilaterally conducting means, such as for example diode **56**, is effectively electrically connected in series with the signal lamps and is capable of conducting electrical current therethrough through at least a portion of the alternating current cycle.

A switching means such as, for example, a relay **68** having a normally-closed contact **70** and a relay coil **72** is operatively connected to the lamp and the unilaterally conducting means such that the position of contact **70** controls conduction of the diode **56**. This is accomplished by normally-closed contact **70** being electrically connected in parallel to the diode **56**. One lead of relay coil **72** is electrically connected to the common neutral **62** while the other lead thereof is electrically connected to the light sensing means **54**. When the relay coil **72** is de-energized, normally-closed contact **70** is in a closed position and selectively bypasses or is connected in parallel to the diode **56** and conducts electrical current through the signal lamps of the indicators. When relay coil **72** is energized, the coil **72** causes the normally-closed contact to be moved to an open position and permits the diode to completely control conduction of the current through the lamps.

In this illustrated intersection of FIGURE 1, the light sensing means **54** includes a photocell **76** which is responsive to the background illumination in the vicinity of the intersection. Photocell **76** has one terminal thereof electrically connected via lead **78** to the hot or energized line of the power distribution system **48**. The other terminal of the photocell **76** is electrically connected to a relay coil **80** which in turn is connected to the system ground of the electrical distribution system **48**. A normally-closed contact **82** controlled by coil **80** is electrically connected before the photocell **76** to the lead **78** is also connected to a control lead **84**. Control lead **84** is in turn connected to the other terminal of relay coil **72** within the control means **52**. When the background illumination in the vicinity of the intersection is at a high level, the resistance of photocell **76** is low allowing coil **80** to be actuated holding contact **82** in an open position. When the background illumination decreases below a preselected level, the resistance of the photocell **76** becomes high reducing the voltage across coil **80** thereby deactuating coil **80** which enables contact **82** to move into its normally-closed position. When contact **82** is in its normally-closed position, relay coil **72** has a voltage applied thereacross from lead **78** causing normally-closed contact **70** to be moved into its open position. When this occurs, the diode **56** is electrically connected in series with each of the signal lamps of the indicators in each of the traffic signal faces **16–22** thereby abruptly dimming traffic signal lamps connected to the rectifier. By using a rectifier as the diode **56**, the power applied to the lamp is decreased to about one-half of its original value and the light intensity drops from about a 100 percent level to about a 26 percent level. The reduction in power and lamp intensity is due to diode **56** conducting only during one-half the portion of the alternating current voltage cycle.

The above represents one possible solution to the problem of dimming traffic signal lamps either in a single phase, a plurality of phases or of the entire intersection. The light responsive electrical lamp dimming system is disclosed and claimed in an application filed concurrently herewith of Stanley L. Ross, identified as Serial No. 742,628.

In certain applications, it is desirable not to abruptly dim the entire intersection but to proportionally dim only selected traffic signal lamps or indications. By using the teachings of the present invention, at least four possible combinations are possible: (1) dimming a single traffic signal lamp or indication in a selected traffic signal face; (2) dimming traffic signal lamps or indications which are identical and in the same phase wherein each lamp is located in a different traffic signal face; (3) dimming traffic signal lamps or indications in a single traffic signal face; and (4) dimming traffic signal lamps or indications in a plurality of traffic signal faces in the same phase. These typical combinations which utilize the teachings of the present invention will now be considered with respect to FIGURES 2 through 5.

FIGURE 2 discloses a single traffic signal face **90** having a red indication **92**, an amber indication **94**, a green indication **96** and a left turn indication **98**. Each of the indications **92–98** is selectively controlled from a traffic signal controller (not shown) via control leads **100–106** respectively. Each of the neutrals of indications **92–98** is electrically connected to a common neutral **110**. The red indication **92** has a light responsive electrical lamp dimming circuit **112** electrically connected in series between it and its associated control lead **100**. Similarly, other light responsive electrical lamp dimming circuits, which are illustrated as dashed line rectangles and designated as **112'** in FIGURE 2, can be selectively connected between other indications **94–98** and the control leads **102–106** respectively. The circuit **112** is capable of proportionally dimming the intensity of the traffic signal lamp only of the red indication of the traffic signal face **90** from a normal or high intensity level to a predetermined intensity level as a function of sensed background illumination. The traffic signal lamps of the remaining indications (without circuits **112'**), namely, amber indication **94**, green indication **96** and left turn indication **98**, remain at normal intensity levels. Thus, a single control circuit **112** connected between the control lead **100** and red indication **92** is capable of proportionally dimming a single traffic signal lamp or indication in a traffic signal face. A light responsive electrical lamp dimming circuit for dimming only a single traffic signal lamp is illustrated in FIGURE 5.

Traffic signal lamps or indications which are identical and in the same phase but located in different traffic signal faces can also be dimmed. For example, two control conductors **116** and **118** to other red indications located in other traffic signal faces (not shown) can be proportionally dimmed by circuit **112**. It is necessary that circuit **112** have a sufficient current carrying capability to dim the desired number of traffic signal lamps. A light responsive electrical lamp dimming circuit for dimming a plurality of traffic signal lamps, as described above, is illustrated in FIGURE 7.

FIGURE 3 illustrates a different traffic signal face **120** which is similar to the traffic signal face **90** of FIGURE 2. However, traffic signal face **120** includes a red indication **122**, an amber indication **124**, a green indication **126** and a right turn indication **128**. Each of the traffic signal lamps of indications **122–128** is selectively controlled via control leads **132–138** respectively, which leads are in turn controlled by a traffic signal controller (not shown). The neutrals from each of the traffic signal lamps of indications **122–128** are electrically connected to a common neutral **140**. Each of the traffic signal lamps of indications **122–128** is illustrated as being electrically connected to the control leads **132–138** respectively via series connected light responsive electrical lamp dimming circuits generally designated as **142–148** respectively, which control leads are in turn controlled by a traffic controller (not shown). By using a separate dimming circuit **142–148** for each indication in a traffic signal face, each traffic signal lamp is proportionally dimmed as a function of sensed background illumination. Thus, either some or all of the traffic signal lamps or indications in a single traffic signal face can be proportionally dimmed. A dimming circuit which can be used as the dimming circuits **142–148** is illustrated in FIGURE 5.

FIGURE 4 illustrates a means for dimming all of the traffic signal lamps or indications in all of the traffic signal faces in the same phase. A traffic signal face **156**, which is typical of a plurality of traffic signal faces in the same phase, is illustrated in FIGURE 4 as having a red indication **158**, an amber indication **160** and a green indication **162**. The traffic signal lamps of indications **158–162** are controlled by control leads **164–168** respectively, which control leads are in turn controlled by a traffic controller (not shown). Each of the neutrals of the lamps of indications **158–162** is electrically connected to a single light responsive electrical lamp dimming means **170**. Dimming means **170** is in turn electrically connected to a common neutral **172** which in turn is connected to the system ground. If a phase utilizes more than one traffic signal face, all of the traffic signal faces in that phase must be electrically connected together and in turn be connected to a single dimming means **170**, having sufficient current carrying capacity, which is in turn connected to the system ground. When a single control circuit **170** is required to control more than one face, a common neutral from each face, such as for example common neutrals illustrated as dashed lines **171** in FIGURE 4, is connected together before the control circuit **170**. In this application, it is necessary that all the common neutrals from the faces on the same phase be connected together such that ground loop problems are eliminated and the desired dimming of the entire phase between a high intensity level and the predetermined low intensity level is obtained. A dimming means **170** for controlling a single phase having a single traffic signal face is illustrated in FIGURE 7.

FIGURE 5 is a schematic diagram of a light responsive electrical lamp dimming circuit which could be used as the dimming circuit **112** and **112'** of FIGURE 2 or as the dimming circuits **142–148** of FIGURE 3. For purposes of example, the dimming circuit illustrated schematically in FIGURE 5 is the dimming circuit **112** of FIGURE 2.

Dimming circuit **112** controls dimming of the traffic signal lamp **92'** of the red indication **92**. The lamp **92'** is electrically connected to the control lead **100** which is selectively switched to a source of alternating current voltage **174** by the traffic signal controller, which is represented by the single pole, single throw switch identified "TSC." Thus, the dimming circuit **112** is essentially electrically connected in series between the lamp **92'**, whose intensity is to be proportionally dimmed, and the control lead **100**. The neutral of lamp **92'** is in turn connected to the common neutral **110**.

The circuit which forms the dimming circuit **112** includes a capacitor **176** electrically connected between the control lead **100** and lamp **92'**. An inductor **178** is electrically connected in parallel to the capacitor **176**. Capacitor **176** and inductor **178** function to suppress undesired radio frequency signals and the like generated within the circuit **112** from being applied across the voltage source **174**. A photocell **182**, which forms part of the background illumination sensing means, is connected to the inductor **178** via resistor **190** and is used to control the sensitivity of a bi-directional triggering means, generally designated as **184**, which is used to control a bi-directional conducting means, generally designated as **186**, which is essentially connected in series with lamp **92'**. The triggering means **184** and the conducting means **186** may be an integral solid state device, generally designated as **188**. The conducting means **186** selectively conducts an electrical current through the lamp **92′**, the magnitude of which depends on the state of conduction of the conducting means at the time it is rendered conductive. The photocell **182** is electrically connected to the lamp **92′** by a capacitor **192**. A variable resistor **194** is electrically connected in parallel to the photocell **182**, and variable resistor **194** is used to adjust the sensitivity level for the triggering means **184**. The predetermined low intensity to which lamp **92′** is to be dimmed is selected by the value of resistance of resistor **194**.

The remaining portion of the background illumination sensing means includes, in addition to the photocell **182**, a light reducing means, generally designated as **198**. In this embodiment, the light reducing means **198** is a red jewel **200** and an apertured disk **202**. The red jewel **200** and apertured disk **202** selectively control the amount of background radiation or light from the background illumination which impinges on the photocell **182**. The resistance of the photocell **182** in turn varies the switching state or phase angle of conduction of conducting means **186**, which in this embodiment is a bi-directional semiconductor device. In this way, the dimming circuit **112** proportionally dims the lamp **92′** as a function of sensed background illumination.

Typically, the operation of the dimming circuit of FIGURE 5 is as follows. The background illumination in the vicinity of the lamp **92′** is sensed by the background illumination sensing means, which in this exemplary embodiment comprises a photocell **182** and a light reducing means **198**. When the background illumination is at a bright level, the light reducing means **198** reduces the level of the illumination to about 2 footcandles or so causing the resistance of the photocell **182** to be at a value which enables the triggering means, which is a triggering circuit formed of resistor **190**, photocell **182**, variable resistor **194**, capacitor **192** and triggering diode **184**, to permit the bi-directional thyristor **186** to conduct at a first state or at a first phase angle of conduction. This permits an electrical current to pass through the lamp **92′** to establish a voltage thereacross for substantially an entire portion of the alternating current cycle which operates the lamp at a high intensity level.

As the background illumination varies from and becomes less than the bright level, the radiation impinging upon the photocell **182** via the jewel **200** and apertured disk **202** also proportionally reduces in intensity. The reduced amount of radiation impinging on the photocell **182** causes the resistance thereof to increase proportionally to the decrease in background illumination level. The increase in resistance of the photocell **182** causes the triggering means or the triggering circuit to vary the state or angle of conduction of the conducting means **186** in proportion to the decrease in background illumination.

When the background illumination reaches a predetermined low intensity level, the intensity of the illumination reaching the photocell is substantially at zero foot-candles and the resistance of the photocell **182** remains at substantially a high value. The resistance of the photocell **182** together with the resistance of resistor **194** establishes the minimum triggering condition of the conducting means **186**. In particular, a second state or second angle of conduction is established wherein an electrical current is passed through the lamp to establish a voltage thereacross for at least a portion of the alternating current voltage cycle which operates the lamp at the predetermined low intensity level. Thus, the conduction of the conducting means **186** is varied between the first state, or first angle of conduction, and the second state, or second angle of conduction, in proportion to sensed changes in background illumination which varies from a bright level to a preselected dark level. When the background illumination is at or below the preset dark level, the intensity of the lamp is maintained at the predetermined low intensity level.

Typical components for the circuit of FIGURE 5 are listed hereinbelow.

Signal lamp **92′**—150 watt tungsten lamp.
Capacitors **176**, **192**—.047 μf., 400 volts.
Inductor **178**—100 μh., torroidal coil, 30 turns of AWG wire on .68″ O.D. x .35″ I.D. x .27″ thick torroidal core
Photocell **182**—G.E. B245
Resistors:
  190—4.7kΩ, ½ watt
  194—500 kΩ potentiometer, ½ watt
Triggering diode **184** and Bi-directional semiconductor device **186** (An integral unit **188**)—Quadrac; Electronic Control Corporation Cat. No. Q2005T

The curve of FIGURE 6 illustrates the characteristics of the dimming circuit of FIGURE 5 using both a red jewel and a yellow jewel as the jewel **200** together with the aperture disk **202** having an aperture in the order of about 1/16 inch (about 2 mm.) to about ⅛ inch (about 3.5 mm.). In FIGURE 6, three curves are illustrated, curve **206** for the circuit using a red jewel which represents the voltage across the lamp as a function of illumination in foot-candles, curve **208** for the circuit using a yellow jewel which represents the voltage across the lamp as a function of background illumination in foot-candles, and curve **210** for the circuit using a yellow jewel which represents the percent light output of the lamp plotted as a function of background illumination in foot-candles. From curve **210**, it is readily apparent that the dimming of the signal lamp is substantially proportional to the background illumination and the percent of light output of the lamp can be selectively controlled between about 15 percent, at a very low background illumination, to slightly more than about 95 percent for a relatively bright background illumination. When the background illumination is in excess of 1200 foot-candles, the percentage light output of the lamp approaches 100 percent.

FIGURE 7 illustrates schematically an embodiment of a circuit for a light responsive electrical lamp dimming circuit **170** of FIGURE 4 for controlling a phase having only a single traffic face. For purposes of explanation, operation of only the traffic signal lamp **158′** of red indication **158** is illustrated. It is understood that the traffic signal lamp for the amber indication **160** and green indication **162** are electrically connected in parallel to the lamp **158′** and would be simultaneously dimmed.

The lamp **158′** is electrically connected to the control lead **164** which is selectively switched to an alternating current voltage source **222** by the traffic signal controller, which is represented by the single pole, single throw switch identified "TSC."

The dimming circuit **170** generally includes a radio frequency filtering network connected across the lamp **158′** and to common neutral **172** which is formed of a resistor **223** connected in series with a capacitor **224** and in parallel to a second capacitor **226**. In addition, the filtering network includes an inductor **228** which is electrically connected in series with the common neutral **172**.

A trimming or extended range circuit, which enables the circuit to operate over a wider range of maximum and minimum limits, is connected across the lamp and to common neutral **172**. The extended range circuit includes a resistor **232** having one end thereof connected to the neutral of lamp **158′** and with the other end of which is connected at a common junction terminal with a capacitor **234** which in turn is connected to a common conductor **230**. Common conductor **230** is connected via inductor **228** to common neutral **172**. The remainder of the extended range circuit includes a second resistor **244** having one end thereof connected to the neutral of lamp **158′** and with the other end thereof connected at a common junction terminal with a capacitor **242** and a resistor ductor 230. The resistor **236** is also connected to the com-**236**. Capacitor **242** in turn is connected to common common junction terminal of resistor **232** and capacitor **234**.

The triggering means or triggering portion of the sensing circuitry includes a photocell **240** which forms part of the background illumination sensing means. The photocell **240** is electrically connected in parallel to resistor **244**. Resistor **244** also serves the function of establishing the predetermined low intensity level of the lamp **158'**. A bi-directional triggering diode **246** is electrically connected to the common junction terminal between photocell **240**, capacitor **242** and resistor **244** and is responsive to the charge built up on capacitor **242** to trigger a bi-directional conducting device **248**, which may be for example a triac.

The background illumination sensing means further includes, in addition to the photocell **240**, a light reducing means, generally designated as **250**, which selectively and proportionally controls the amount of background radiation or intensity representing the background illumination which reaches the photocell **240**. In this embodiment, the light reducing means **250** includes a jewel, generally designated **252**, and an apertured disk **254**. The combination of the jewel **252** and apertured disk **254** controls the amount of radiation of the background illumination which is directed upon and impinges upon photocell **240**. The radiation directed upon the photocell **240** varies as a function of the changes in background illumination in the vicinity of the traffic signal face **156** and in turn varies the resistance of the photocell to provide a substantially linear dimming of the lamp **158'** in proportion to sensed changes in background illumination.

The operation of the dimming circuit of FIGURE 7 is very similar to the dimming circuit of FIGURE 5. Thus, a detailed description of circuit operation as a function of sensed changes in background illumination is not deemed necessary.

It is important that the operational characteristics of the background illumination sensing means be selected or matched, so to speak, with the lumen level of the background illumination.

As discussed hereinbefore, a photocell abruptly changes its resistance from a low resistance to a high resistance in response to about 2 foot-candles to about zero foot-candles of illumination respectively. By means of the light reducing means as disclosed herein, the illumination which is directed onto the photocell varies over this range of 2 foot-candles, but does so in proportion to the background intensity. In this manner, the background illumination can vary over a wide range of illumination levels, such as for example from about 1200 foot-candles to zero foot-candles, and the intensity of the controlled lamp can be varied by the photocell in proportion to the change in background illumination.

In summary, the background illumination sensing means must be capable of providing a change in operational characteristics as a function of and substantially in proportion to the change in background illumination. The change in operational characteristics disclosed herein is a change of resistance of a photocell. The amount of light which impinges on the photocell is selectively reduced, or filtered in these embodiments, by a light reducing means. A change in light energy which impinges onto the photocell causes a change in resistance thereof which is proportional to the changes in background illumination. In the absence of such a light reducing means, it was determined that a photocell, not so selected or compensated, operated substantially as a bi-directional switch.

Typical components capable of being used in the embodiment of FIGURE 7 are set forth hereinbelow.

Lamp **158'**—G.E. Model #123–1, 150 watt, 120 v. A.C.
Resistor **223**—82Ω
Capacitor:
 224—.22μf., 400 volts
 226—.047μf., 200 volts
Inductor **228**—100μh., torroidal coil, 30 turns of AWG wire on .68" O.D. x .35" I.D. x .27" thick torroidal core
Resistor **232**—68kΩ
Capacitor **234**—.1μf., 400 volts
Resistor:
 236—12kΩ
 244—82kΩ (could vary depending on photocell from 50kΩ to 100kΩ)
Capacitor **242**—.1μf.
Photocell **240**—G.E. B425
Bi-directional triggering diode **246**—G.E. ST2
Triac **248**—G.E. SC41B

Table I hereinbelow discloses the operation characteristics of the circuit of FIGURE 7. In Table I, background illumination is shown in foot-candles in both a westerly and an easterly direction and the lamp precent illumination viewing in an easterly direction and voltage applied across the lamp is shown wherein the light reducing means is a red jewel with an apertured disk having about a 1/16 inch (approximately 2 mm.) aperture. Clearly, the dimming of the lamp is proportional to the decrease in background illumination.

TABLE I

(Around sunset) background illumination (foot-candles) West	East	Remarks	Time between readings (min.)	Lamp percent, illumination	(East viewing) light reducing means (volts) red jewel with aperature disk 1/16" (2 mm.)
500+	500+	Sun up	0	100	123
500+	500+	do	7	88	118
500+	500+	do	15	82	115
500+	350	Sun behind cloud	21	82	115
500+	240	do	17	75	112
500+	180	Sun up	10	71	110
220	90	Sun behind cloud	12	55	103
160	70	Sun half down	10	49	100
45	15	Sun down	9	36	94
19	6	do	6	31	90
6	2	do	10	27	88
2	.8	do	8	27	88
0	0	do	7	27	88

E_{Line}=125 volts (Open circuit); $E_{Line}-E_{Photocell}$=123 volts (Photocell in circuit); Photocell: G.E. B425.

Table II hereinbelow discloses the operating characteristics of the circuit of FIGURE 7 showing the lamp percentage illumination for a different light reducing means; namely, a blue jewel with a red filter instead of an apertured disk. In Table II, background illumination is shown in foot-candles in a westerly, easterly and overhead direction and shows the lamp percentage illumination viewing in both an easterly and westerly viewing direction. In this Table II, it is readily apparent that the dimming of the controlled lamp is proportional to the sensed changes in background intensity.

TABLE II

Background illumination (foot-candles)			Remarks	Time between readings (min.)	Lamp percent, illumination	Light reducing means blue jewel with red filter (volts)	
West	East	Overhead				East	West
1,225	400	1,175	Behind cloud	0	99.4	122	122
6,400	650	1,800	Sum up	15	99.4	123	123
1,600	240	400	do	70	92.4	120	124
400	140	240	Sun up tree	20	81.9	116	120
180	65	150	Sun half down	10	74.6	112	119
100	34	82	Sun down	10	60.8	106	115
26	8	21	do	10	43.1	95	106
10	8	3	do	10	35.8	92	100
4	.5	3	do	7	30.5	90	96
2	.1	1	do	5	25.5	87	91
0	0	0	Stars out	5	25.0	87	88
0	0	0	Almost dark moon	8	23.5	86	86
0	0	0	Dark	5	23.5	86	86
			Taped		23.5	86	86

E_{Line}=125 volts; $E_{Line}-E_{Photocell}$=123 volts; Photocell: G.E. B425.
(Open circuit) (Photocell in circuit)

FIGURE 8 is a graph showing a curve **266** which represents the percent light output as a function of voltage across the lamp in FIGURE 7 when a yellow jewel is used for the jewel **252**.

FIGURE 9 is a fragmentary cross-sectional elevational side view of an assembled and packaged circuit of FIGURE 5 installed in a traffic signal section. The assembled and packaged circuit is generally illustrated as **272**. The rearwardly located and lower exterior walls of a traffic signal housing are represented by cross-sectional housing **274**. The rearwardly located exterior wall is drilled and tapped to form a threaded aperture **276** which is adapted to receive a threaded yellow plug member **278**. The yellow plug member **278** may be a S. S. White special plastic protector part #1604–80–Y described in their catalog dated August 1965 having a diameter of ⅝ inch (about 1.6 cm.) and a pitch of 18 threads per inch (about 18 threads per 2.54 cm.). The yellow plug member **278** has an outer flange **280** which is spaced from the rearwardly located exterior wall of housing **274** by means of a waterproof gasket **282**. The overall dimension of flange **280** is approximately ⅞ inch (about 2.25 cm.). The top portion of the threaded yellow plug member **278** has a slot **286** which is adapted to receive the bit of a screwdriver for threading the yellow plug member **278** into threaded aperture **276**. The slot **286** also forms a thin outer wall section of the plug **278** which enables the portion of the plug just below the slot to form a filter for background illumination. The center of the plug member **278** is hollowed-out so as to form a light passage area **290**. An apertured disk **292** is located within the hollowed-out area or light passage area **290** and adjacent the portion of the yellow plug member **278** just below slot **286**.

Thus, background illumination in the vicinity of the traffic signal section passes through the slot **286** of the plug member **278** and is generally focused to a small beam having a predetermined cross-sectional area by means of the apertured disk **292** (having a diameter in the order of a few mils). The light beam then passes through the hollowed-out area **290** and impinges upon an aligned photocell which is located in the packaged circuit **272**. In this manner, the amount of background illumination impinging on the photocell within the packaged circuit **272** selectively changes the resistance of the photocell such that proportional control and dimming can be obtained. In this embodiment, if the plug member **278** and the apertured disk **292** were omitted, the photocell would merely abruptly change its resistance when the background illumination reached a certain level. When this occurs, the device is then operative as a bi-stable switching device.

By using these teachings, a relatively inexpensive, effective and waterproof light responsive electrical lamp dimming system can be easily installed into existing traffic signal control systems.

FIGURE 10 is a fragmentary cross-sectional elevational side view of an assembled and packaged circuit of FIGURE 7 installed in a traffic signal section similar to that of FIGURE 9. The assembled and packaged circuit is generally illustrated as **300**. The rearwardly located and lower exterior walls of a traffic signal section are illustrated in cross-section with the rearwardly located exterior wall designated as **302**. Exterior wall **302** has a threaded aperture **306** which is adapted to receive a threaded nipple **308** such that the end of the nipple **308** protrudes or extends slightly beyond the outer surface of exterior wall **302**. A red jewel member **310** has a threaded adjustable collar **312** which is adapted to be threaded onto the extended or protruding portion of the nipple **308** such that the red jewel member **310** is supported in the alignment with the end of the nipple **308**. Also located at the end of the nipple **308** and in alignment with the red jewel member **310** is an apertured disk **314**. Disk **314** receives the radiation from the background illumination from red jewel member **310** and functions to limit the radiation from the background illumination to a predetermined cross-sectional area. The interior or center of nipple **308** permits the limited amount of background illumination passing through apertured disk **314** to impinge on the photocell (**240** of FIGURE 7) which is located in the packaged circuit **300** adjacent the other end of nipple **308**.

In this embodiment, the red jewel member **310** and the apertured disk **314**, in combination, selectively permit a limited amount of background illumination to impinge upon and vary the resistance of the photocell as a function of the change in background illumination. The change in resistance of the photocell enables circuit **300** to variably dim the traffic signal lamp in proportion to the sensed change in background illumination. The packaged circuit **300** as described herein together with the nipple **308**, red jewel member **310**, collar **312** and apertured disk **314** can be easily installed into an existing traffic signal section.

It is readily apparent from the embodiments described herein that many other combinations, modifications, improvements and the like can be made of the light responsive electrical lamp dimming system, circuits and means disclosed herein and all are deemed to be within the scope of the appended claims.

What is claimed is:

1. A light responsive electrical lamp dimming means comprising

a pair of leads one of which is adapted to be electrically connected in series with a lamp to be dimmed;

a controllable bi-directional conducting means capable of being selectively rendered conductive electrically connected in series with said leads;

triggering means electrically connected in parallel with and operatively connected to said bi-directional conducting means which, when an alternating current voltage is applied across said series connected lamp and said bi-directional conducting means, selectively varies the state of conduction of said bi-directional conducting means between a first state wherein an electrical current is passed through said lamp to establish a voltage thereacross for substantially an entire portion of the alternating current cycle which is capable of operating said lamp at a high intensity level and a second state wherein an electrical current is passed through said lamp to establish a voltage thereacross for at least a portion of the alternating current voltage cycle which is capable of operating said lamp at a predetermined low intensity level; and

background illumination sensing means adapted to detect changes in background illumination in the vicinity of said lamp and operatively connected to and capable of controlling said triggering means for varying conduction of said bi-directional conducting means between said first state and said second state in proportion to sensed changes in background illumination.

2. The electrical lamp dimming means of claim **1** further comprising means operatively coupled to said triggering means for disabling control thereof in response to said background illumination sensing means when said background illumination decreases below a preselected dark level and for establishing conduction of said bi-directional conducting means at said second state whereupon said lamp remains at said predetermined low intensity level whenever said background illumination is at a level below said preselected dark level.

3. The electrical lamp dimming means of claim **2** wherein said background illumination sensing means includes

a light reducing means disposed to receive and selectively transmit light from said background illumination as a light beam having an intensity which varies in proportion to the changes in said background illumination; and

a light sensing means capable of varying its resistance as a function of light incident thereon operatively coupled to said triggering means and positioned adjacent to and in alignment with said light reducing means to receive said light beam for controlling operation of said triggering means in response to said sensed changes in said background illumination.

4. A light responsive electrical lamp dimming system adapted to be connected in series with a lamp which is energized from a source of alternating current voltage for proportionally controlling intensity of said lamp between a high intensity level and a predetermined low intensity level as a function of background illumination in the vicinity of said lamp, said system comprising

a controllable bi-directional semiconductor device adapted to be electrically connected in series with a lamp for controlling conduction of an electrical current through said lamp when bi-directional semiconductor device is rendered conductive;

triggering means operatively connected to said bi-directional semiconductor device for selectively varying conduction thereof between a first state wherein an electrical current is passed through said lamp to establish a voltage thereacross for substantially an entire portion of the alternating current cycle which operates said lamp at said high intensity level and a second state wherein an electrical current is passed through said lamp to establish a voltage thereacross for at least a portion of the alternating current voltage cycle which operates said lamp at said predetermined low intensity level;

means operatively coupled to said triggering means for disabling control thereof when said lamp reaches said predetermined low intensity level for setting the conduction state of said bi-directional semiconductor device at said second state whereupon said lamp remains at said predetermined low intensity level whenever said triggering means attempts to change conduction of said bi-directional semiconductor device to a state which is other than between said first and second states; and

background illumination sensing means adapted to detect changes in background illumination in the vicinity of said lamp, said background illumination sensing means comprising

means for selectively transmitting light from said background illumination along a predetermined path, and

light responsive means operatively coupled to said triggering means and positioned along said path and adapted for receiving light from said background illumination to control said triggering means for varying conduction of said bi-directional semiconductor device between said first state and said second state in proportion to sensed changes in background illumination.

5. The electrical lamp dimming system of claim **4** wherein said selectively transmitting means includes

a filter disposed to receive and selectively transmit, along said predetermined path, light from said background illumination as a light beam which varies in intensity in proportion to changes in said background illumination; and

an apertured disk positioned along said predetermined path between said filter and said light responsive means for reducing said light beam to a predetermined cross-sectional area.

6. A light responsive electrical lamp dimming apparatus comprising

an electrical circuit comprising

a pair of leads one of which is adapted to be electrically connected in series with a lamp to be dimmed,

a bi-directional gate controlled switch electrically connected in series with said leads and said lamp, said gate controlled switch being capable of being selectively rendered conductive when an alternating current voltage is applied across said series connected lamp, leads and gate controlled switch, and

a triggering circuit operatively connected in parallel to said gate controlled switch and operatively connected to the gate of said gate controlled switch, said triggering circuit including

a bi-directional triggering diode having one of its leads electrically connected to the gate of said gate controlled switch,

a photocell electrically connected between the other lead of said bi-directional triggering diode and said one lead connected in series with said lamp,

a capacitor electrically connected between said other lead of said bi-directional triggering diode and the other of said pair of leads, and

resistance means electrically connected to said photocell and the other lead of said bi-directional triggering diode for establishing a minimum angle of conduction at which said bi-directional triggering diode can render said bi-directional gate controlled switch conductive; and

light reducing means positioned adjacent said photocell and adapted to selectively transmit light of an intensity level which varies the resistance of said photocell in proportion to change in intensity level of background illumination in the vicinity of said lamp.

7. A light responsive electrical lamp dimming means adapted for use with a traffic signal control system energized from an alternating current voltage source wherein said dimming means proportionally controls intensity of a traffic signal lamp between a high intensity level and a predetermined low intensity level as a function of background illumination in the vicinity of the traffic signal lamp, said dimming means comprising

a controllable bi-directional conducting means adapted to be electrically connected in series with said lamp for selectively controlling conduction of an electrical current through said lamp as a function of the phase angle and voltage amplitude of the alternating current voltage when said conducting means is rendered conductive;

triggering means operatively connected to said controllable bi-directional conducting means for selectively varying the angle of conduction thereof between a first angle of conduction wherein an electrical current is passed through said lamp to establish a voltage thereacross for substantially an entire portion of an alternating current cycle which operates said lamp at a high intensity level and a second angle of conduction wherein an electrical current is passed through said lamp to establish a voltage thereacross for at least a portion of an alternating current cycle which operates said lamp at a predetermined low intensity level; and

background illumination sensing means capable of detecting background illumination in the vicinity of said lamp for controlling said triggering means to vary the angle of conduction of said controllable bi-directional conducting means between said first conduction angle and said second conduction angle in proportion to changes in sensed background illumination.

8. The electrical lamp dimming means of claim 7 further comprising means operatively coupled to said triggering means for disabling control thereof by said background illumination sensing means when said background illumination decreases below a preselected dark level when said triggering means has established conduction of said controllable bi-directional conducting means at said second angle which operates said lamp at said predetermined low intensity level whenever said background illumination level is below said preselected dark level.

9. The electrical lamp dimming means of claim 8 wherein said background illumination sensing means includes

a light reducing means disposed in a traffic signal face of said traffic control system and positioned to receive and selectively transmit light from said background illumination directly behind said traffic signal face as a light beam having an intensity which varies in proportion to the changes in said background illumination; and

a light sensing means capable of varying its resistance as a function of incident light thereon operatively coupled to said triggering means and positioned adjacent to and in alignment with said light reducing means to receive said light beam for controlling operation of said triggering means in response to changes in said background illumination.

10. The electrical lamp dimming means of claim 7 wherein said dimming means is electrically connected between a control lead and a single traffic signal lamp of a traffic signal face.

11. The electrical lamp dimming means of claim 10 adapted for use in an intersection having at least a one phase traffic controller wherein said dimming means is electrically connected between all of the traffic signal lamps of the same indication located in different traffic signal faces in the same phase.

12. The electrical lamp dimming means of claim 10 wherein a separate said dimming means is electrically connected between more than one traffic signal lamp and its associated control lead in the same traffic signal face.

13. The electrical lamp dimming means of claim 10 adapted for use in an intersection having at least a one phase traffic controller wherein said dimming means is electrically connected between the common neutrals of all traffic signal faces of the same phase.

14. The electrical lamp dimming means of claim 7 wherein said source of alternating current is capable of being a voltage of approximately 120 volts, 60 Hz. and wherein the intensity of said traffic signal lamp can be varied from between about 100 percent intensity level and about 23 percent intensity level.

15. The electrical lamp dimming means of claim 9 wherein said light reducing means includes

a filter disposed to receive and selectively transmit along a predetermined path said light from said background illumination as said light beam which varies in intensity in proportion to changes in said background illumination; and

an apertured disk positioned along said predetermined path between said filter and said light sensing means for reducing said light beam to a predetermined cross-sectional area.

16. The electrical lamp dimming means of claim 15 wherein said controllable bi-directional conducting means is a bi-directional gate controlled switch and wherein said triggering means further comprises

a bi-directional triggering diode having one of its leads electrically connected to the gate of said gate controlled switch and its other lead electrically connected to said light sensing means;

a capacitor electrically connected between the other leads of said bi-directional triggering diode and the output of said gate controlled switch; and

resistance means electrically connected to said light sensing means and to the other lead of said bi-directional triggering diode for establishing said second angle of conduction at which said bi-directional triggering diode can render said bi-directional gate controlled switch conductive.

17. The electrical lamp dimming means of claim 11 further comprising a radio frequency suppressing circuit electrically connected across said bi-directional gate controlled switch.

18. The electrical lamp dimming means of claim 16 wherein said bi-directional gate controlled switch is a triac and wherein said light sensing means is a photocell.

19. The electrical lamp dimming means of claim 18 wherein said resistance means is a resistor electrically connected in parallel with said photocell.

20. The electrical lamp dimming means of claim 18 wherein said filter is selected to be a yellow jewel and said apertured disk has an aperture of about 1/16 inch.

21. The electrical lamp dimming means of claim 18 wherein said filter is selected to be a red jewel and said apertured disk has an aperture of about 1/16 inch.

22. The electrical lamp dimming means of claim 21 further comprising

a radio frequency suppressing circuit electrically connected between said lamp and said triac; and

an extended range circuit electrically connected between said radio frequency suppressing circuit and said triac.

(References on following page)

References Cited

UNITED STATES PATENTS

3,027,491	3/1962	Seidler	315—159
3,265,932	8/1966	Petterson	315—292
3,133,264	5/1964	Fieser et al.	340—40
3,283,297	11/1966	Pfennighausen et al.	340—22
3,416,032	12/1968	Jahns et al.	315—149

JOHN W. HUCKERT, Primary Examiner

SIMON BRODER, Assistant Examiner

U.S. Cl. X.R.

315—154, 194; 340—40, 335