

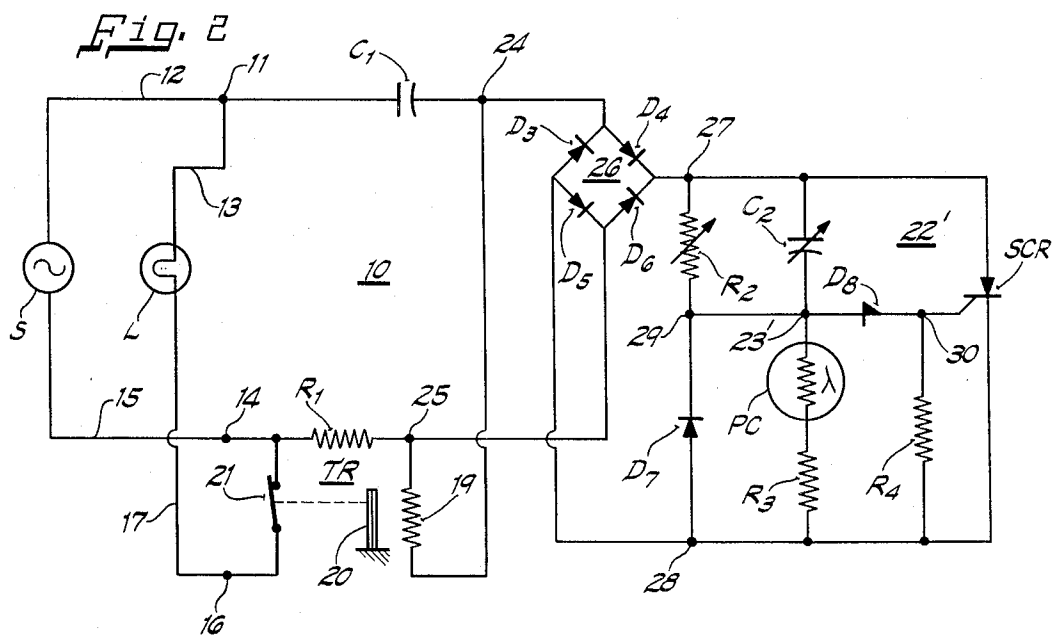
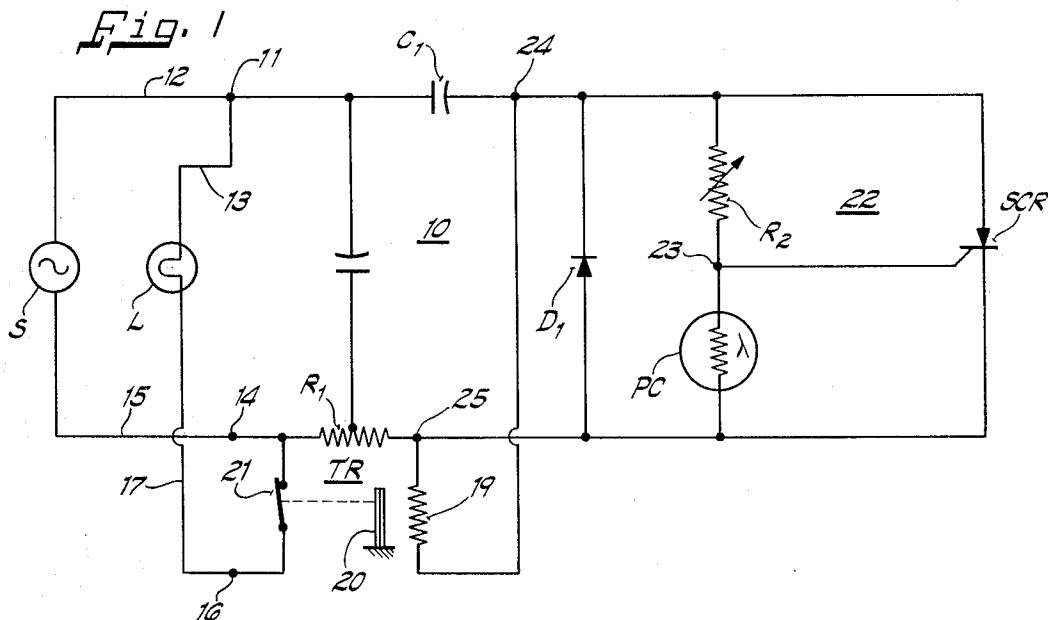
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PHOTO-CONTROL DEVICE EMPLOYING THERMAL RELAY

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1

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PHOTO-CONTROL DEVICE EMPLOYING
THERMAL RELAY

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This invention relates to photo-control devices and more particularly to photo-control devices employing thermal relays.

One type of photo-control device employs a thermal relay having a heater resistor element connected in series with a photo-sensitive resistor or photocell whose resistance varies with ambient illumination. During periods of darkness the resistance of the photo-sensitive resistor is relatively high so that the magnitude of the current flowing to the heater resistor is insufficient to operate the thermal relay. As the level of illumination increases to a threshold level, the photocell resistance decreases so that the current through the series combination will increase to cause actuation of the thermal relay.

Photo-control devices employing thermal relays have been unsatisfactory for the control of outdoor lighting because the photocells of such devices are susceptible to burnout as a result of overloading and voltage surges. Voltage surges in the power line supplying the photo-control can produce burnout as a result of photocells' large resistance during periods of darkness. As a result, photo-control devices employing thermal relays of this type require lightning arresters or discharge tubes. Photocell overloading may result from the fact that the photocell carries the entire heater resistor current so that during certain periods of operation the IR drop across the photocell may become excessive, causing burnout.

Thermal relays of the type employed in photo-control devices generally include a thermally responsive member, such as a bimetallic element which is caused to deflect and displace a movable contact as a result of the heat generated by the heater resistor. Because the amount of such deflection depends upon the current level which in turn varies with illumination, the elements of prior art devices deflect only a relatively small distance at the threshold illumination level. As a result, contact size and separation in prior art devices was relatively limited.

Photo-control devices having series connected thermal relay resistance heaters and photocells do not always "turn on" at the same light levels because at least some current flows to the heater resistor at all times. Thus, if the light level decreases slowly the slow buildup of current through the heater will cause the device to turn on at a higher light level than when the ambient illumination decreases rapidly.

Because of these shortcomings in photocontrol devices having thermal relays, most commercial photo-control devices for street lighting applications use more expensive electromagnetic relays.

Another shortcoming of prior art photo-control devices is that there is no accurately attainable ratio of turn-off to turn on illumination levels. It is desirable to have the photo-control turn the lamp on at slightly lower illumination levels than that at which it is turned off so that temporary shadows cast on the photocell by such things as perching birds will not cause the lamp to be turned on.

It is an object of the invention to provide a photo-control device wherein the energy dissipated by the photocell thereof is limited to a relatively small value regardless of the level of illumination.

A further object of the invention is to provide a photo-control device wherein the voltage applied to the photocell is held to a limited value irrespective of surge voltages appearing at the power supply system.

2

Another object of the invention is to provide a photo-control device wherein the energy dissipated by the heater resistor of the thermal relay changes from a substantially zero value to a substantially constant high value when the threshold illumination value is reached so that relatively large contact separation and contact size may be achieved.

Still another object of the invention is to provide a photo-control device which has an accurately adjustable ratio of turn on illumination levels.

A more specific object of the invention is to provide a photo-control device with switching circuit means having control means coupled to a photo-sensitive resistance and switching circuit means shunting an electroresponsive output means wherein the electroresponsive output means will be bypassed when the level of ambient illumination reaches a predetermined value. A still more specific object of the invention is to provide such photocontrol devices wherein the switching circuit means includes a controlled rectifier.

These and other objects and advantages of the instant invention will become more apparent from the detailed description thereof taken with the accompanying drawings in which:

FIG. 1 schematically illustrates one embodiment of the instant invention; and

FIG. 2 schematically illustrates an alternate embodiment of the instant invention.

Referring now to the drawings in greater detail, FIG. 1 shows a photo-control device designated by the general reference numeral 10 for connecting and disconnecting a lamp L to an alternating current energy source S. The photo-control device 10 is provided with a first terminal 11 connected by conductors 12 and 13 to the energy source S and the lamp L, respectively, a second terminal 14 connected by conductor 15 to the other side of the energy source S and a third terminal 16 connected by conductor 17 to the other side of the lamp L.

The photo-control 10 also includes a thermal relay TR of any well-known type which may, for example, include a heater resistor 19, a bimetallic element 20 and contacts 21 in circuit between terminals 14 and 16. A switching circuit 22 controls current flow to the heater resistor 19 in accordance with the illumination falling on a photocell PC so that when the illumination level is low, little or no current flows through the heater resistor 19. As a result, bimetallic element 20 is relaxed and contacts 21 are closed so that terminals 14, 16 are interconnected whereby the lamp L is energized. On the other hand, when the ambient illumination level is such that the lamp L is not required, a relatively high current will flow through the heater resistor 19 so that contacts 21 will be opened and the lamp L deenergized.

The photocell PC is of the photo sensitive resistance type and may be, for example, of cadmium sulfide, lead sulfide or selenium and have a resistance which varies inversely to the intensity of the ambient illumination to which the photocell is exposed.

The heater resistor 19 is connected in series with a ballast capacitor C₁ and a current-limiting resistor R₁ and the combination is connected across the terminals 11 and 14.

The switching circuit 22 includes a first diode D₁ connected in shunt with terminals 24 and 25 of the heater resistor 19, a silicon controlled rectifier SCR whose anode and cathode are connected in shunt with the heater resistor 19 and a variable resistor R₂ and a photocell PC which are serially connected to each other and the series combination also connected in shunt with the terminals 24, 25. The junction 23 between the resistor R₂ and the photocell PC is connected to the gate electrode of the SCR.

It will be appreciated that alternating potential will appear at the terminals 24 and 25 of the heater resistor 19

3

so that when terminal 25 is positive, diode D_1 will bypass current around the heater resistor 19. When the terminal 24 is positive, however, a current path will be provided through the ballast capacitor C_1 , the variable resistor R_2 , the photocell PC and the resistor R_1 . If the resistance of PC is very low, corresponding to a high level of ambient illumination, there will be insufficient IR drop thereacross to fire the SCR so that the latter will remain in its non-conductive condition. As a result, current will also flow through the heater resistor 19 so that contacts 21 will be open and the lamp L will be off.

As the level of ambient illumination falls, the resistance of the photocell PC will increase, causing a corresponding increase in the voltage drop between terminals 23 and 25. At the threshold ambient illumination value, occurring at dusk, the voltage drop across photocell PC during each half-cycle when the terminal 24 is positive, will be equal to the firing potential of the gate of the SCR, causing the SCR to fire and short-circuit terminals 24 and 25. As a result, no current will flow through the heater resistor 19 during the remainder of this half-cycle. Because terminals 24 and 25 are also short-circuited during the other half-cycle, i.e., when terminal 25 is positive, no current will flow through the heater resistor 19 during either half-cycle. As a result, the bimetallic element 20 will return to its relaxed condition to close contacts 21 and thereby place the lamp L across the source S. This will continue as long as the illumination level is below the turn-off threshold value. At dawn, however, the ambient illumination will pass the turn-off threshold value causing the drop across photocell PC to decrease below that required to fire the SCR and current will again begin flowing through heater resistor 19 during alternate half-cycles so that the bimetallic element 20 will deflect to open contacts 21 and deenergize lamp L.

Should a negative voltage surge appear in the lines 12-15, it will be bypassed around the switching circuit 22 by the diode D_1 so that no inordinate voltage is applied to the photocell PC. A positive voltage surge, on the other hand, will cause the voltage drop across photocell PC to rise until the potential at junction 23 is sufficient to fire the SCR whereupon terminals 24 and 25 are short-circuited so that no further voltage rise can occur across PC. Since the voltage required to fire an SCR is in the order of one volt applied to the gate, it can be seen that the maximum voltage occurring across PC as a result of voltage surges will not exceed this value. As a result, the photocell device according to the instant invention is not subject to photocell burnout as a result of voltage surges.

It can also be seen that the photocell PC does not carry the current flowing to the heater resistor 19 as in conventional devices, nor does it perform a power handling function. The photocell PC merely acts as a monitor for the controlled rectifier SCR which performs the power handling function. As a result, the highest voltage that can be applied to the photocell PC is that required to turn the SCR on, since the photocell PC is short-circuited when the SCR becomes conductive. As stated hereinabove approximately one volt potential drop across PC is required to fire the SCR and, accordingly, this is the highest voltage applied to the photocell PC. It can, therefore, be seen that the photo-control according to the instant invention does not subject its photocell PC to potentially damaging high voltages during normal operation.

In the alternate embodiment of the invention shown in FIG. 2, a full-wave rectifier 26 consisting of diodes D_3 , D_4 , D_5 , and D_6 is connected between the heater resistor terminals 24, 25 and the input terminals 27, 28 of the switching circuit 22' so that a pulsating voltage wave appears at the terminals 27 and 28. A resistor R_2 and a diode D_7 are connected in series across terminals 27 and 28 and the junction 29 between them is connected to the junction 23' between firing capacitor C_2 and photocell PC. Resistor R_2 serves to permit the discharge of firing capacitor C_2 when the pulsating voltage applied across terminals

4

27 and 28 is at its minimum value. Diode D_7 prevents the junction 23' from swinging negative when the pulsating voltage from rectifier 26 is at its minimum value. A resistor R_3 is connected in series with the photocell PC and provides surge protection along with resistor R_1 and another resistor R_4 interconnects the gate and cathode electrodes of silicon control rectifier SCR to provide a path for leakage current in the SCR. A four-layer diode D_8 connects the junction 23' between firing capacitor C_2 and photocell PC and the junction 30 between R_4 and the gate of SCR.

A four-layer diode is a bi-stable device characterized in that it presents an open circuit when its anode to cathode potential is below a predetermined value and a closed circuit after this potential exceeds this value.

Operation of the device shown in FIG. 2 is similar to that illustrated in FIG. 1. The pulsating current appearing at the terminals 27 and 28 passes through firing capacitor C_2 , photocell PC and resistor R_3 . When the level of ambient illumination is high, during daylight hours, the voltage drop across PC and resistor R_3 is less than the breakdown potential of the four-layer diode D_8 so that flows through the heater resistor 19. As a result, the bi-controlled rectifier SCR is non-conductive and current metallic element 20 is deflected to hold contacts 21 open and the lamp L deenergized.

When the level of ambient illumination decreases to the threshold value, the IR drop across the series combination of the photocell PC and resistor R_3 reaches the breakdown potential of four-layer diode D_8 and the latter will break down permitting capacitor C_2 to discharge through D_8 and into the gate of controlled rectifier SCR. The application of gate current to controlled rectifier SCR will cause it to become conductive and short-circuit terminals 27 and 28. As a result, the output terminals of the full wave rectifier 26 are short-circuited so that current no longer flows through the heater resistor 19 and the element 20 relaxes to close contacts 21 and energize the lamp L.

The diode D_8 is added in the embodiment of FIG. 2 to overcome the temperature sensitivity of the controlled rectifier SCR. Thus, in FIG. 2 the operation of the controlled rectifier SCR will be determined by the breakdown potential of D_8 rather than varying slightly with temperature as in the embodiment of FIG. 1.

Surge protection is provided in the embodiment of FIG. 2 by resistors R_1 and R_3 . Resistor R_1 serves to control the rate of rise of voltage in capacitor C_1 under surge conditions and a large enough R_1 resistance is provided to prevent capacitor C_1 from charging to a dangerously high level during surge voltages. The current incident to a voltage surge will also cause the voltage at the output of the bridge rectifier to raise rapidly. This rapid rate of voltage rise will in turn cause a relatively large current to pass through capacitor C_2 and photocell PC in series with resistor R_3 . As soon as the voltage across diode D_8 reaches its breakdown value, the controlled rectifier SCR will fire and short-circuit the bridge rectifier to remove the surge voltage from all components except capacitor C_1 which is protected by resistor R_1 . It can be seen, therefore, that under voltage surge conditions the photocell PC can never be subjected to a voltage greater than the breakdown potential of diode D_8 .

The purpose of resistor R_3 connected in series with PC is to insure a certain minimum resistance value for the series combination of photocell PC and resistor R_3 . Otherwise, at high illumination levels the resistance of the photocell PC might be low enough to cause an appreciable over-voltage to occur across the bridge rectifier before there is sufficient voltage developed across diode D_8 to fire control rectifier SCR.

Another feature of the embodiment of FIG. 2 is that by adjusting the value of R_2 relative to C_2 , the ratio of turn-on to turn-off light levels can be controlled.

The turn-on level of ambient illumination is lower than

5

the turn-off level as a result of the fact that the current through the capacitor C_2 , and hence that through photocell PC, is proportional to the rate of change of voltage across C_2 and further because the applied voltage signal is a rectified sine wave. As a result, the rate of change of voltage across capacitor C_2 , and hence its current, will decrease as the quantity of initial charge on the capacitor increases. Since capacitor C_2 is substantially fully charged as the ambient illumination level approaches the turn-on level, the current flowing to photocell PC from C_2 will be at a relatively lower level so that a greater PC resistance is required and accordingly a lower level of illumination. However, it will be recalled that capacitor C_2 discharges through the gate of SCR to initiate a turn-on operation and this continues for each half cycle so that for each half-cycle after the initial one, C_2 is substantially discharged whereby the rate of change of voltage across it is relatively higher. Thus, the current flowing to the photocell PC after a turn-on operation is relatively higher than immediately before so that lower PC resistance, and hence a lower illumination level, is required to keep the device turned on.

It will be apparent that between each half-cycle, capacitor C_2 will discharge somewhat through resistor R_2 at a rate dependent upon the size of R_2 . Thus, by making R_2 adjustable the current flowing from C_2 to the photocell PC for any given illumination level before the firing of controlled rectifier SCR can also be adjusted. In this manner, the turn-on level of illumination for the control 10 may be adjusted.

It will be appreciated from the foregoing discussion of each of the embodiments of the invention illustrated in FIGS. 1 and 2 that because the photocell PC does not handle power to the heater resistor 19 but acts merely to monitor this power flow, the voltage applied to the photocell PC during both normal operating and surge voltage conditions is limited to a relatively small value so that the danger of photocell burnout is minimized.

It will be further appreciated that the current flow through the heater resistor 19 goes directly from substantially zero when the SCR is conductive to a full value when the SCR is nonconductive. There will, therefore, be no periods, such as at the threshold illumination levels, when the heater resistor 19 current is relatively low. As a result, full deflection of the bimetallic element 21 will be available at all periods of thermal relay TR operation so that relatively large contact separation and contact size may be achieved at the contacts 21.

While only two embodiments of the instant invention have been shown and described, and while the invention has been illustrated with respect to the control of a particular type of device, it is not intended to be limited thereby but only by the scope of the appended claims.

I claim:

1. In a photo-control device, input means for providing unidirectional potential, electroresponsive output means connected across said input means, photo-sensitive resistance means in circuit with said input means, electronic means having a control electrode and a pair of output electrodes and producing a substantially zero impedance path between said output electrodes when a predetermined potential appears at said control electrode and a substantially infinite impedance path between said output electrodes when less than said predetermined potential appears at said control electrode, said output electrodes being connected in a shunt circuit relation with said electroresponsive output means and said control electrode being connected to said photosensitive resistance means so that the potential on said control electrode is a function of ambient illumination incident on said photo-sensitive resistance means, whereby said output means will be bypassed when the level of ambient illumination reaches a predetermined value said electronic means also being constructed and arranged to produce said sub-

6

stantially zero impedance path between said output electrodes when a potential appears at said input means which is substantially higher than the normal potential appearing thereat.

2. In a photo-control device, a pair of terminals for connection to a source of alternating potential, thermal means connected to said terminals, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected in a shunt circuit relation relative to said thermal means, a photo-sensitive resistor in circuit with said terminals and the gate electrode of said controlled rectifier for providing a gate voltage signal inversely related to the level of ambient illumination.

3. In a photo-control device, input means for providing unidirectional potential, electroresponsive output means connected to said input means, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected in a parallel circuit relation to said input means, a photo-sensitive resistor and impedance means connected in series across said input means and having a common terminal, the gate electrode of said controlled rectifier being connected to said common terminal to provide a gate potential inversely related to the level of ambient illumination, whereby said output means will be short-circuited when the level of ambient illumination falls below a predetermined value.

4. In a photo-control device, input means for providing unidirectional potential, thermally responsive means having a resistance heater connected to said input means, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected in a parallel circuit relation to said resistance heater, a photo-sensitive resistor and impedance means connected in series across said input means and having a common terminal, the gate electrode of said controlled rectifier being connected to said common terminal to provide a gate potential inversely related to the level of ambient illumination, whereby said resistance heater will be short-circuited when the level of ambient illumination falls below a predetermined value.

5. In a photo-control device, a pair of input terminals for connection to a source of alternating potential, thermally responsive means connected across said input terminals, a diode connected across said input terminals in a first sense, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected across said input terminals in an opposite sense, a photo-sensitive resistor and an impedance connected in series across said input terminals, the gate electrode of said controlled rectifier being connected to the junction between said photo-sensitive resistor and said impedance to provide a gate potential inversely related to the level of ambient illumination, whereby said thermally responsive means will be short-circuited when the level of ambient illumination falls below a predetermined value.

6. In a photo-control device, a pair of terminals constructed and arranged for connection to a source of alternating potential, a thermal relay having a resistance heater connected across said terminals and a thermally responsive member, a diode connected in a first sense across said terminals, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected in an opposite sense across said terminals, a photo-sensitive resistor and an impedance connected in series across said terminals, the gate electrode of said controlled rectifier being connected to the junction between said photo-sensitive resistor and said impedance to provide a gate potential inversely related to the level of ambient illumination, so that said resistance heater will be short-circuited when the level of ambient illumination falls below a predetermined value.

7. A three terminal photo-control device having a pair of terminals constructed and arranged for connection to a source of alternating potential, a thermal relay including a resistance heater having a pair of electrodes

connected across said pair of terminals and a normally closed thermally responsive member constructed and arranged to connect one of said pair of terminals to a third terminal, an impedance means in circuit between said electrodes and said pair of terminals, a diode connected in a first sense across said electrodes, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected in an opposite sense across said electrodes, a photo-sensitive resistor and an impedance connected in series across said electrodes; the gate electrode of said controlled rectifier being connected to the junction between said photo-sensitive resistor and said impedance to provide a gate potential inversely related to the level of ambient illumination, so that said resistance heater will be short-circuited when the level of ambient illumination falls below a predetermined value whereby said thermally responsive member will close to connect the one of said pair of terminals to said third terminal.

8. A three terminal photo-control device, a pair of said terminals being constructed and arranged for connection to a source of alternating potential, impedance means connected in series circuit relation between said pair of said terminals, a thermal relay having a resistance heater connected across said pair of terminals and a normally closed thermally responsive member constructed and arranged to connect one of said pair of terminals to said third terminal, full wave rectifying means having an input connected across said pair of terminals, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected across the output of said rectifying means, a photo-sensitive resistor and a capacitor connected in series across the output of said rectifying means, diode means characterized by an open circuit when the potential thereacross is below a predetermined value and a closed circuit after said value has been exceeded, said diode connecting the gate electrode of said controlled rectifier to the junction between said photo-sensitive resistor and said capacitor to provide a gate potential inversely related to the level of ambient illumination, so that said resistance heater will be short-circuited when the level of ambient illumination falls below a predetermined value whereby said thermally re-

sponsive member will close to connect the one of said pair of terminals to said third terminal.

9. A three terminal photo-control device having a pair of terminals constructed and arranged for connection to a source of alternating potential, a thermal relay including a resistance heater having a pair of electrodes connected across said pair of terminals and a normally closed thermally responsive member constructed and arranged to connect one of said pair of terminals to said third terminal, a first capacitance and a resistance in circuit between said electrodes and said pair of terminals, full wave rectifying means having an input connected across said electrodes, a controlled rectifier having a gate electrode and having anode and cathode electrodes connected across the output of said rectifying means, a photosensitive resistor and a second capacitance connected in series across the output of said rectifying means, diode means characterized by an open circuit when the potential thereacross is below a predetermined value and a closed circuit after said value has been exceeded, said diode connecting the gate electrode of said controlled rectifier to the junction between said photosensitive resistor and said second capacitance to provide a gate potential inversely related to the level of ambient illumination, so that said resistance heater will be short-circuited when the level of ambient illumination falls below a predetermined value whereby said thermally responsive member will close to connect the one of said pair of terminals to said third terminal and adjustable resistance means connected in parallel circuit relation to said second capacitance.

10. The photocontrol device set forth in claim 1 wherein said electronic means comprises a PNP semiconductor device.

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