

[54] **REMOTE CONTROL CIRCUIT FOR
CONSTANT CURRENT REGULATOR**

[75] Inventors: **Robert E. Babcock**, Danville, Ill.;
Wayne R. Neal, Hendersonville,
N.C.

[73] Assignee: **General Electric Company**

[22] Filed: **Nov. 4, 1970**

[21] Appl. No.: **87,010**

Related U.S. Application Data

[62] Division of Ser. No. 837,014, June 27, 1969, Pat. No. 3,609,515.

[52] U.S. Cl. **307/115, 320/1, 323/19, 323/23**

[51] Int. Cl. **G05f 3/04**

[58] Field of Search **307/115; 320/1; 323/22 SC, 323/24, 34, 6, 19, 23, 25**

References Cited

UNITED STATES PATENTS

3,098,214 7/1963 Windes et al. 320/1 X
3,375,403 3/1968 Flieder 323/34 UX

3,445,752 5/1969 Horvat 320/1 X
3,501,771 3/1970 Miller et al. 323/34 X

Primary Examiner—A. D. Pellinen
Attorney, Agent, or Firm—Sidney Greenberg

[57] **ABSTRACT**

Current regulator device used for lighting circuits to control lamp brightness. A moving coil transformer has a main secondary winding connected to an illuminating load and an auxiliary secondary winding associated with the main secondary winding, and SCR phase control device is connected to the auxiliary secondary winding for controlling the current therein and thereby the current in the main secondary winding and the load. The SCR control device is triggered by a transistor and pulse transformer circuit synchronized with the voltage from the alternating current supply which is rectified by a bridge circuit. A remote control circuit for operating the regulator to produce different brightness levels includes a plurality of parallel-connected transistor circuits having individually adjustable resistors.

4 Claims, 3 Drawing Figures

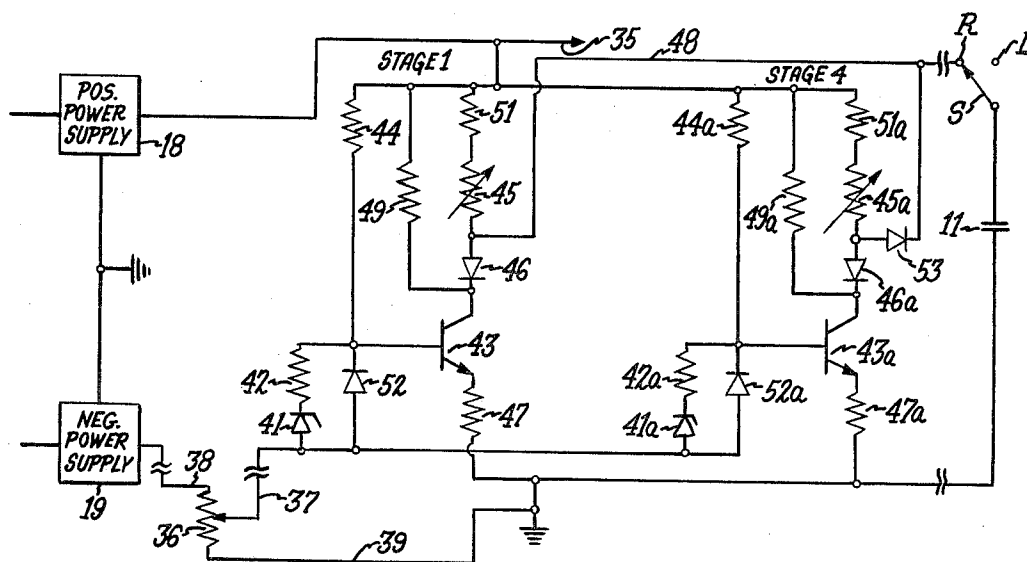
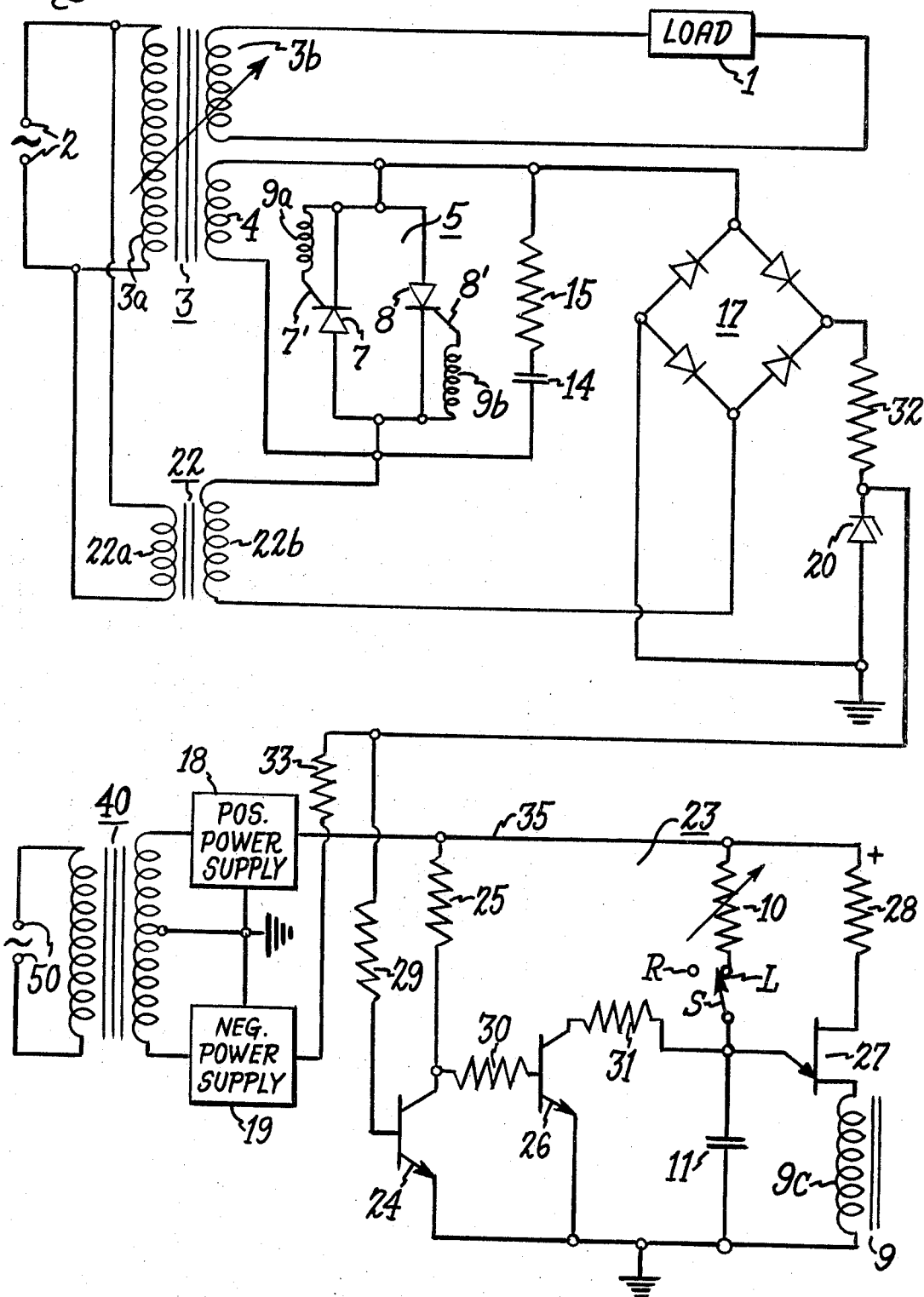
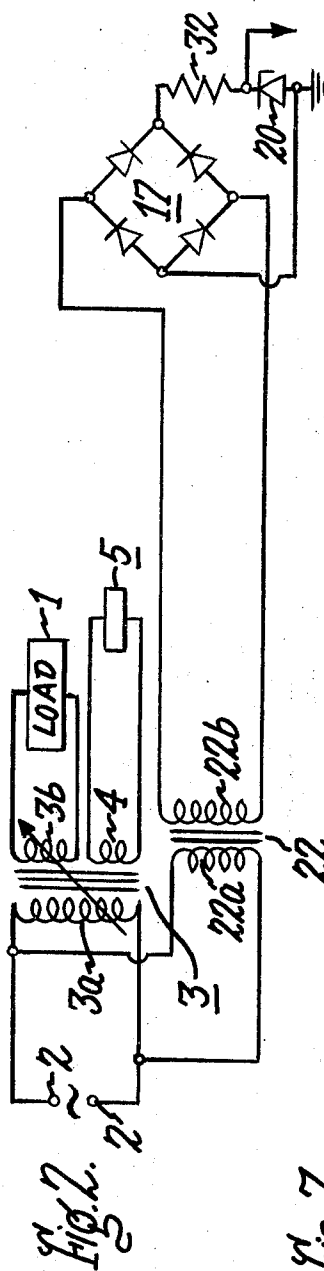
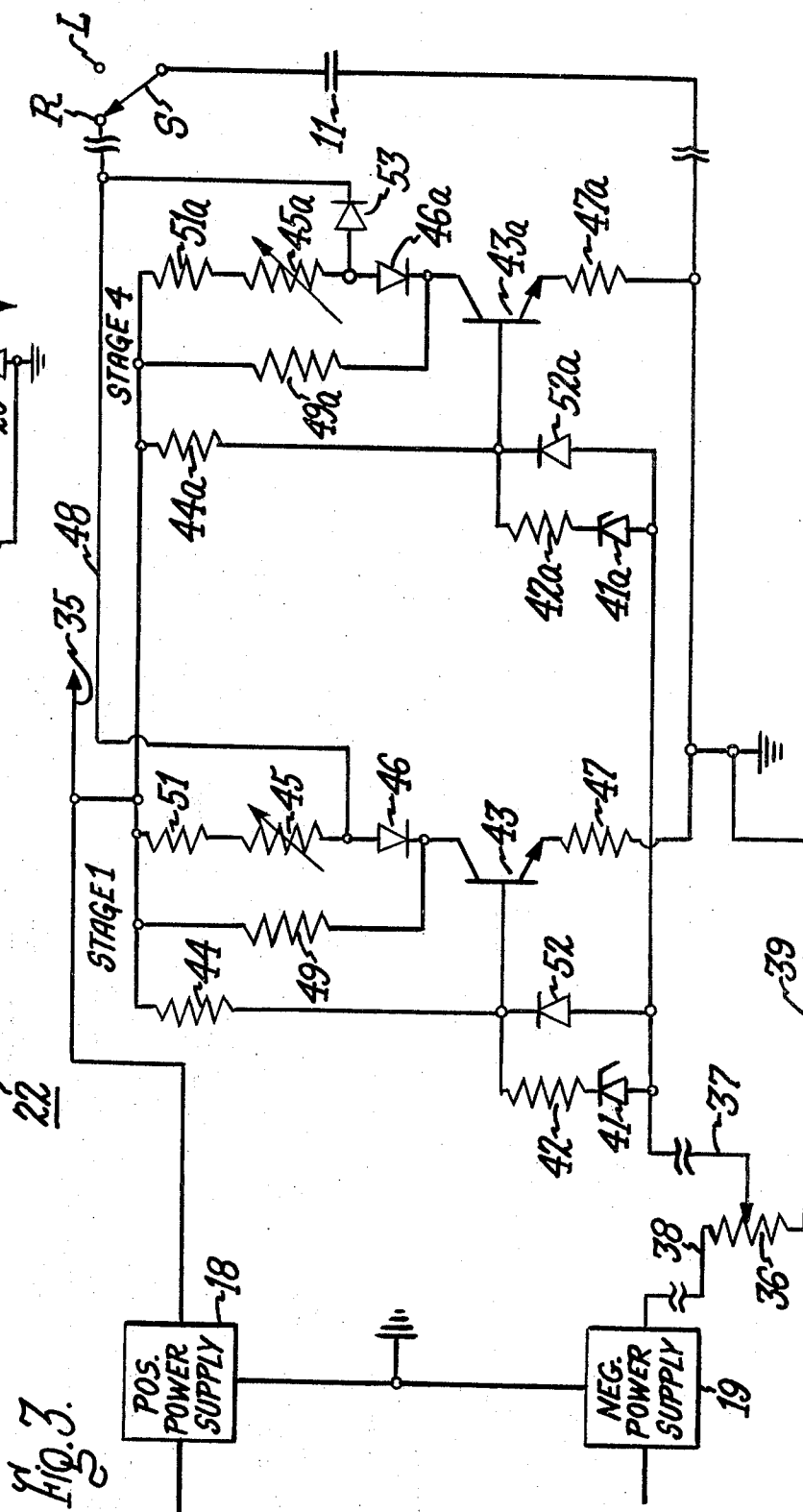


Fig. 1.





REMOTE CONTROL CIRCUIT FOR CONSTANT CURRENT REGULATOR

This application is a division of application Ser. No. 837,014, filed June 27, 1969, and assigned to the same assignee as the present invention, now Pat. No. 3,609,515 issued Sept. 28, 1971.

The present invention relates to constant current regulators, and more particularly to such regulators used in lighting circuits for supplying selected levels of current to lamps for controlling their brightness.

Among lighting circuits of the above type in which the invention may advantageously be employed are those used for lighting airport runways and in which the lamp brightness is controlled in accordance with visibility conditions at the airport.

It is an object of the invention to provide an adjustable control circuit for controlling the operation of constant current regulators, especially of the type used in lighting circuits for controlling the light level produced therefrom.

A particular object of the invention is to provide a control circuit of the above type which may be employed for remote control purposes and has improved stability and adjustability.

Other objects and advantages will become apparent from the following description and the appended claims.

With the above objects in view, the present invention in one of its aspects relates to a current regulator device comprising, in combination, a unidirectional current supply, a current control circuit comprising variable resistance means connected to the unidirectional current supply and a transistor connected at its base to the current supply and having its collector connected to the variable resistance means, a charging capacitor connected to the junction of the variable resistance means and the transistor collector and to the emitter of the transistor, the capacitor and the variable resistance means forming an RC time constant circuit, and means connected to the transistor for at least partially turning off the same for controlling the operation thereof and thereby the operation of the RC time constant circuit, the latter means comprising a second unidirectional current supply of polarity opposite that of the first-mentioned unidirectional supply, and connected to the base of the transistor.

The invention will be better understood from the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a circuit diagram of a constant current regulator device embodying a synchronizing arrangement in accordance with the invention;

FIG. 2 is a circuit diagram of a modification of the synchronizing arrangement of the FIG. 1 circuit; and

FIG. 3 is a circuit diagram of a remote control circuit constructed in accordance with the invention which may be employed with the constant current regulator device shown in FIG. 1.

Referring now to the drawings, and particularly to FIG. 1, there is shown a circuit arrangement energizing at a constant current a load 1, such as an illuminating means. The illuminating means may be constituted by one or more lamps, such as incandescent, gaseous discharge or fluorescent-type lamps. The circuit includes a movable coil constant current transformer 3 comprising a main primary winding 3a connected to terminals

2 of a source of alternating current and a main secondary winding 3b across which load 1 is connected. In such a movable coil transformer 3, either primary coil 3a or secondary coil 3b may be made movable on the core relative to the other. As well understood in the art, such a transformer is a variable impedance device that provides a constant output current to a range of load impedances throughout a limited variation in the primary supply voltage, and corrects any variations in output current by changing the variable impedance in series with the load. In such a device, the output current is constant at a particular level depending on the structure of the core and coils and the ampere-turn relationship of the coils. In the regulator circuit employed in the invention, a control device is incorporated for varying in stepless fashion the level of the constant output current which would otherwise be fixed. The control device as shown in FIG. 1 comprises an auxiliary secondary winding 4 adjacent main secondary winding 3b and in fixed spatial relation thereto. Connected across auxiliary secondary winding 4 is a controlled rectifier switching circuit 5 which serves to provide a phase controlled current of desired amount in winding 4 to thereby vary the ampere-turns of main secondary coil 3b, and thus resulting in the desired adjustment of the constant current supplied to load 1. Controlled rectifier circuit 5 includes a paralleled pair of oppositely poled controlled rectifiers 7 and 8, which are typically silicon controlled rectifiers (SCR) having control (gate) electrodes 7' and 8' by means of which the SCR's are rendered conductive for unidirectional flow of current when a signal pulse is applied to the respective control electrodes. A power semiconductor symmetrical switch could be used to replace the two SCR's.

Control electrodes 7' and 8' are connected respectively to secondary windings 9a, 9b of pulse transformer 9, of which the primary is arranged in actuating circuit 23 described below. Transformer 9 serves to isolate controlled rectifier circuit 5 from the trigger pulse generating circuit described below and to provide pulses of the proper polarity and voltage to control electrodes 7' and 8'.

The signal generating or actuating circuit 23 for triggering the operation of SCR switching circuit 5 comprises solid state semiconductor components, as more fully disclosed below, to provide improved stability and reliability in the operation of the triggering means. To provide unidirectional current for energizing triggering circuit 23, full-wave rectifying bridge 17 is connected in series with auxiliary secondary winding 4 across SCR switching circuit 5. The negative output terminal of bridge 17 is grounded, as shown, and the positive output terminal is connected by a current limiting resistor 32 to a voltage clamping device 20 such as a Zener diode and to transistor 24 of trigger circuit 23. Transistor 24 is arranged with its base connected to bridge 17 by a current limiting resistor 29, its collector connected by a resistor 25 to a separate positive power supply 18 and its emitter connected to pulse transformer primary 9c and the common ground. Connected at its base to the collector of transistor 24 via resistor 30 is transistor 26, which is connected across capacitor 11 with resistor 31 in series with its collector. Resistor 25 limits the current to the collector of transistor 24 and the base of transistor 26, and resistor 30 ensures that transistor 26 does not turn on while transistor 24 is conductive. Re-

sistor 31 limits the collector current of transistor 26 which results from discharge of capacitor 11.

Capacitor 11 is connected in series with variable resistor 10 and provides therewith an RC time constant network connected at one side to power supply 18 and at the other side to transformer primary 9c. In the illustrated embodiment, a switch S, which may be manually operated, is provided for connecting capacitor 11 via terminal L to variable resistor 10 which serves as a local control, or for alternatively connecting capacitor 11 to the remote control circuit described below by moving switch S in contact with terminal R, as seen in FIG. 3. Connected in series discharge relation with capacitor 11 and transformer primary 9c is unijunction transistor (UJT) 27 which has a first base (base two) connected via current limiting resistor 28 to the positive power supply 18 and a second base (base one) connected to transformer primary 9c.

Power to triggering circuit 23 is furnished by an auxiliary alternating current source having terminals 50 to which is connected the primary of step-down transformer 40. Connected in series with the secondary of transformer 40 are positive power supply 18 and negative power supply 19, each of which may be of well-known construction and need not be described herein in detail. Circuit arrangements providing such supply currents of the respective polarities are disclosed, for example, in the General Electric Company Transistor Manual, 7th edition, 1964, in Chapter 10, e.g., FIG. 10.1. Alternatively, the desired positive and negative currents could be derived simply from DC batteries appropriately connected in the circuit. Power supply devices 18 and 19 and a center tap on the secondary winding of transformer 40 are connected to a common ground, as shown, to provide for independent operation of the positive and negative power supplies. Positive power supply 18 is connected by conductor 35 to triggering circuit 23 as previously described, and negative power supply 19 is connected via current limiting resistor 33 to the junction of resistor 32 and Zener diode 20.

For the purpose of synchronizing the SCR trigger pulses with the SCR anode voltage there is provided a step-down transformer 22 having its primary winding connected across supply terminals 2 and its secondary winding connected at one side to SCR switching circuit 5 and at the other side to bridge 17 as shown. In effect, bridge 17 is thus arranged in series with both secondary windings 4 and 22b and as a result it vectorially adds the two voltages thereof, and the resultant rectified voltage, reduced by resistor 32, is applied to the base of transistor 24 through current limiting resistor 29.

In the operation of the described circuit, on each half cycle of the alternating current input derived from auxiliary secondary winding 4, one of the controlled rectifiers 7 and 8 will have a positive anode and the other a positive cathode. Therefore, a control signal applied to control electrodes 7' and 8' will place only one of the controlled rectifiers in a conduction mode on each half cycle. A delay in the point in the alternating current input cycle at which the control signal impulse is applied to render the rectifier conductive is known as phase control.

In the operation of actuating circuit 23, transistor 26 is normally biased on by virtue of its connection to positive power supply 18 and thus prevents capacitor 11 from becoming charged. When the input current ap-

plied by bridge 17 to the base of transistor 24 is sufficient, e.g., about 50 micro-amperes, transistor 24 is turned on, thus turning off transistor 26, and allowing capacitor 11 to charge through variable resistor 10 until its voltage level reaches the switching voltage of UJT 27, e.g., about 13 volts, at which time UJT 27 fires and discharges capacitor 11 through the discharge loop which includes transformer primary 9c. UJT 27 turns off when current from capacitor 11 drops below the required holding current, and there is thus provided a signal pulse of particular duration and time transmitted by transformer 9 alternately to the gate electrodes of SCR's 7 and 8. The controlled rectifier 7 or 8 which has an anode positive with respect to its cathode will then be triggered into conduction by the pulse current applied to control electrode 7' or 8' and the voltage which has built up across the controlled rectifier falls substantially to zero. The controlled rectifier 7 or 8 then permits a finite amount of current to flow in the auxiliary secondary winding 4 for the remainder of that half cycle. On the next half cycle as the anode voltage becomes negative, the controlled rectifier 7 or 8 which was conductive becomes non-conductive and no current is transferred to winding 4 until the signal generating circuit fires the other controlled rectifier. The time in the half cycle at which the rectifier is gated is adjustable by the level of resistance 10.

Since the output of diode bridge 17 is always present except when the alternating current voltage applied thereto reverses value, i.e., at zero point, transistor 24 is always on except briefly at the zero voltage value. Thus, transistor 26 is switched on only at current zero, thereby synchronizing the charge on capacitor 11 with the voltage across SCR switching circuit 5.

In order to ensure that the bridge output voltage is reduced sufficiently to turn off transistor 24 (at zero point), negative power supply 19 is connected as shown via resistor 33 and Zener diode 20 to the bridge output so that the DC voltage thereof is forced to a slightly negative value at the zero crossing of the applied alternating current. In this arrangement the Zener diode serves as an ordinary forward biased diode drop for the negative supply current. Thus, power supply 19, resistor 33 and Zener diode 20 constitute a simple voltage divider. Zener diode 20 serves, in addition, to limit the excursion of positive voltage to a predetermined value e.g., 10 volts, which is compatible with optimum function of the transistors in actuating circuit 23.

In a typical regulator circuit of the described arrangement for airport runway lighting, terminals 2 are connected to a voltage supply of about 2,400 volts a-c and transformer 22 steps down this voltage to 230 volts a-c. Terminals 50 of the control circuit typically are connected to a supply of 120 volts a-c, and positive and negative supply devices 18, 19 provide about 20 volts output in their respective polarities.

As variable resistor 10 is varied from full resistance to minimum resistance, the current through coil 4 would, in the illustrative arrangement, vary from 0 amperes to about 80 amperes, and the current through load 1 would vary from about 6.6 amperes to about 2.8 amperes.

FIG. 2 shows a modification of the FIG. 1 circuit, wherein the output of bridge 17 is derived only from transformer 22. As shown, both sides of secondary winding 22a are connected to the input terminals of bridge 17, and neither secondary winding 22a or bridge

17 are directly connected to SCR switching circuit 5 or auxiliary secondary winding 4 as in the FIG. 1 arrangement. The modified circuit still provides the desired synchronization of SCR anode voltage and trigger pulses since the output voltage of transformer 22 bears a constant phase relationship to the SCR voltage.

When a constant current regulator of the described type is used for such applications as an airport runway lighting where brightness levels of the lamps must be adjusted in accordance with visibility conditions, it is usually necessary or desirable to provide for quick and reliable adjustment of the lamp brightness from a remote location. FIG. 3 shows a remote control circuit arrangement using solid state semiconductor components which may be combined with the circuits of FIG. 1 or FIG. 2. The remote control circuit includes an adjustable resistor or potentiometer 36 connected at one side by conductor 38 to negative power supply 19, its adjustable tap being connected by conductor 37 to a plurality of parallel-connected transistor circuits providing different stages of brightness levels of the lamp load, and the other side of potentiometer 36 being connected to the transistor circuitry by conductor 39 e.g., the common ground lead. Conductors 37, 38 and 39 are as long as necessary to enable adjustable resistor 36 to be placed in a remote location such as the control tower for operating the regulator device at the desired distance. Shown in FIG. 3 are only the first and last stages of the remote control circuit, designated stage 1 and stage 4, but it will be understood that additional stages of like circuits may be included therebetween, and typically a total of four such stages, each including a variable resistor as described below, would be employed in an airport runway lighting system of the above-described type.

The first switch stage comprises transistor 43 connected at its base to positive power supply 18 via current limiting resistor 44 and having its collector also connected to power supply 18 via variable resistor 45 and diode 46. The emitter of transistor 43 is connected to ground via resistor 47. Conductor 48 connects the collector of transistor 43 to remote control terminal R, to which switch contact S is moved to allow control by the remote potentiometer 36. An auxiliary collector current path with resistor 49 is provided across variable resistor 45 to provide proper collector current value for optimum operation of transistor 43. Diode 46 serves to isolate the auxiliary collector current from the charge path of capacitor 11. Resistor 51 in series with variable resistor 45 provides a minimum resistance in this branch to protect transistor 43 from excessive current.

To control the operation of transistor 43 to change the brightness of lamp load 1, the base of transistor 43 is connected to negative power supply 19 via remote potentiometer 36, with Zener diode 41 and current limiting resistor 42 being arranged in series therewith. By application of negative current to the transistor base sufficient to equal or exceed the positive current thereon, transistor 43 will turn off, with the results described more fully below.

Stage 4 comprises a similar circuit in parallel with the stage 1 circuit and like components thereof are designated by corresponding numerals.

Zener diode 41 of stage 1 has a selected voltage level less than that of Zener diode 41a of stage 4, so that transistor 43a of the latter stage will not be turned off at the same value of negative current. As will be under-

stood, the corresponding Zener diodes in any intermediate stages will have different values between those of stage 1 and stage 4, so that the transistors in successive stages may be turned off in sequence by adjustment of remote potentiometer 36 to obtain desired lamp brightness levels.

In the operation of the described circuit, when remote potentiometer 36 is adjusted to provide sufficient resistance so that no negative current passes through Zener diode 41 (or any corresponding Zener diode of the circuit) the transistors of all stages will be turned on by virtue of the positive current which is applied to the bases thereof. Consequently, transistors 43, 43a conduct the current to ground and no current is applied to capacitor 11 for charging it. As a result, SCR switching circuit 5, shown in FIG. 1, is not triggered and lamp load 1 is therefore at full brightness level. In order to reduce the brightness to the next lower level, stage 1 of the remote control circuit is actuated by adjusting potentiometer 36 to allow sufficient current to exceed the Zener level of Zener diode 41 but not sufficient to pass the Zener diodes of subsequent stages. As a result, transistor 43 is turned off, so that positive current passes through variable resistor 45 and conductor 48 to capacitor 11. By suitable adjustment of variable resistor 45, the rate of charging of capacitor 11 and hence the amount of current available to lamp load 1 will be correspondingly varied to reduce the lamp brightness to the desired level as explained above.

When potentiometer 36 is adjusted to provide sufficient negative current to actuate both stages 1 and 4 (as well as any intermediate stages), all the transistors will be turned off and capacitor 11 will be charged at a correspondingly higher rate to provide for a corresponding reduction of lamp brightness to the minimum level.

Diode 52 arranged in parallel with Zener diode 41 serves to limit negative current excursion to avoid damage to the transistor. Diode 53 shown in stage 4 provides necessary isolation between the parallel stages. Resistor 42 in series with the Zener diode should be low enough in value to provide current adequate to turn off transistor 43 and to forward bias diode 52, and high enough to avoid drawing excessive current, so as to allow the necessary negative current to flow to succeeding stages of the circuit. Resistor 47 provides temperature stability for the transistor and an increase in input impedance to afford optimum bias current.

Stepless adjustment of lamp brightness is obtainable with the described remote control circuit, since the amount of negative current which passes the respective Zener diodes may be varied by suitable adjustment of remote potentiometer 36, and such variation in small increments will correspondingly vary the amount of positive current diverted by operation of transistor 43 to conductor 48 for charging capacitor 11.

Although not shown, means such as current transformers may be provided, if desired, in the main secondary circuit to monitor the load current therein for the purpose of operating such devices as an ammeter and an open circuit voltage protector of known type.

While the described constant current regulator device has been disclosed particularly with respect to its use in an airport lighting system, it will be understood that it may also be found useful for control of other lighting equipment or of other types of apparatus which it is desired to operate at adjustable levels of constant

current, as, for example, various types of heating devices. Moreover, the remote control circuit described and shown herein may be found useful for application to other types of apparatus than the lighting systems described herein.

While the present invention has been described with reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the scope of the invention. Accordingly, we wish to have it understood that we intend herein to cover all such modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by letters Patent of the United States is:

1. Adjustable control device comprising, in combination, a unidirectional current supply, a current control circuit comprising variable resistance means connected to said unidirectional current supply and a transistor connected at its base to said current supply and having its collector connected to said variable resistance means, a charging capacitor connected to the junction of said variable resistance means and said transistor collector and to the emitter of said transistor, said capacitor and said variable resistance means forming an RC time constant circuit, and means connected to said transistor for at least partially turning off the same for controlling the operation thereof and thereby the operation of the RC time constant circuit.

2. A device as defined in claim 1, said last-mentioned means comprising a second unidirectional current supply of polarity opposite that of said first-mentioned unidirectional current supply, and connected to the base of said transistor.

3. A device as defined in claim 2, and an adjustable resistor connected between said second unidirectional

current supply and said transistor base in series therewith.

4. Adjustable control device comprising, in combination, a unidirectional current supply, a current control circuit comprising variable resistance means connected to said unidirectional current supply and a transistor connected at its base to said current supply and having its collector connected to said variable resistance means, a charging capacitor connected to the junction of said variable resistance means and said transistor collector and to the emitter of said transistor, said capacitor and said variable resistance means forming an RC time constant circuit, and means connected to said transistor for at least partially turning off the same for controlling the operation thereof and thereby the operation of the RC time constant circuit, said last-mentioned means comprising a second unidirectional current supply of polarity opposite that of said first-mentioned unidirectional current supply, and connected to the base of said transistor, an adjustable resistor connected between said second unidirectional current supply and said transistor base in series therewith, and at least another current control circuit comprising a second transistor and a second variable resistance means corresponding to and in parallel with said first-mentioned current control circuit, and a plurality of parallel-connected voltage limiting means of different voltage levels respectively connected to the transistors of the first and second mentioned current control circuits and in series with said adjustable resistor for sequentially turning off the respective transistors upon adjustment of said adjustable resistor, and current blocking means isolating said resistances in the respective current control circuits from each other.

* * * * *

40

45

50

55

60

65