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AUTOMATIC HEADLAMP CONTROL SYSTEM

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This invention relates to light responsive control systems and more particularly to control systems for automatically switching vehicle headlamps from upper beam to lower beam in response to the incident light from headlamps of oncoming vehicles. Such systems commonly employ a photomultiplier tube as the light responsive element which, despite its many advantages, imposes certain design problems on the system. The photomultiplier tube, which requires high voltage energization, exhibits a relationship between the incident light and the output current which is very sensitive to the voltage applied to the electrodes. In order to obtain accuracy in the operation of such a system it is necessary to maintain the energizing voltage at an accurately controlled value. In accordance with this invention, a circuit is provided for precise adjustment of the high voltage on the photomultiplier tube by effecting variations in a low voltage circuit of the power supply. This is accomplished by utilizing a power supply including a transistor oscillator of the type which develops an output voltage having an amplitude determined by the bias voltage of the input circuit which is supplied from a battery and voltage regulator and adjusted by a voltage divider circuit.

Also such systems commonly provide for changing the sensitivity of the system to incident light when the control circuit operates to switch the vehicle headlamps from upper beam to lower beam. It is advantageous to utilize the aforementioned characteristic of a photomultiplier tube to obtain sensitivity change but switching action in a high voltage circuit is undesirable. It is a further characteristic of the photomultiplier tube that the current multiplication, from cathode to anode by virtue of the interposed secondary emitters or dynodes, increases exponentially with the number of dynodes. Recognizing that decreasing the effective number of dynodes greatly reduces the current and hence sensitivity and that the voltage across each dynode is relatively low, the desired sensitivity change is accomplished most efficiently by this invention at low voltage. Accordingly, a switching circuit is provided across selected dynodes to vary the voltage thereof upon operation of the control circuit to switch the vehicle headlamps from upper beam to lower beam.

A more complete understanding of this invention may be had from the detailed description which follows taken with the accompanying drawing in which the single figure of the drawing is a schematic diagram of the inventive control system.

Referring now to the drawing, there is shown an illustrative embodiment of the invention in an automatic headlamp control system for automotive vehicles. The system comprises generally the direct current voltage source or battery 10 for energizing the voltage regulator 12 which supplies low voltage to the transistor oscillator 36 for developing a high voltage for the photomultiplier tube 14. The photomultiplier tube develops a control voltage for the control circuit including electron tube 74 and control relay 16 which is adapted to control the

power relay 18 for switching the vehicle headlamps from upper beam to lower beam.

Considering the system in detail, the battery 10 has one terminal connected to a point of reference potential or ground and the other terminal connected through the manual selector switch 20 to the voltage regulator 12. In the voltage regulator, the battery voltage is applied across the ballast tube 22 in series with the resistor 24 and variable resistor 26 to ground. The resistor 30 is connected through the regulated voltage conductor 28 to ground. A voltage divider circuit including the potentiometer resistor 32 and the fixed resistor 34 is connected between the regulated voltage conductor 28 and ground to provide an adjustable value of regulated voltage on the movable contact of the potentiometer resistor 32.

In order to develop a high value of energizing voltage for the photomultiplier tube 14 there is provided a transistor oscillator 36. This oscillator comprises a transistor 38 having the usual emitter, collector and base electrodes and suitably of the PNP junction type. The oscillator has an input circuit extending from the emitter electrode to the movable contact of the potentiometer resistor 32 and thence through resistor 34 to ground and through a base resistor 40 to the base electrode. Accordingly, the emitter to base circuit is biased in the forward direction by the regulated voltage of the potentiometer resistor 32. The output circuit of the oscillator 36 extends from the emitter electrode to the movable contact of the potentiometer resistor 32 and through the resistor 34 to ground and thence through the primary winding 42 of transformer 44 to the collector electrode. Accordingly, the emitter and collector electrodes are biased in the reverse direction and the emitter to base current flow in the input circuit, produced by the voltage across voltage divider resistors 32 and 34, will initiate and sustain current flow in the output circuit. A feedback circuit is connected between the emitter and base electrodes and includes a feedback winding 46 on transformer 44 and a timing or blocking condenser 48. Feedback winding 46 is connected in a regenerative fashion so that current flow in the output circuit causes a voltage to be induced in the feedback winding in a direction to increase the forward bias voltage from base to emitter electrodes. Thus, the output circuit current increases and at the same time a voltage is accumulated upon timing condenser 48 due to the feedback current flow and is of such polarity that the base electrode becomes increasingly positive relative to the emitter electrode. The circuit parameters are so related that as the output circuit current reaches a saturation value, the timing condenser voltage drives the base electrode sufficiently positive to cut off conduction in the output circuit. After the cut-off condition is reached, the condenser 48 discharges through the resistor 50 and feedback winding 46. The process just described providing alternate conduction and non-conduction in the output circuit is repetitive at a frequency and pulse duration determined largely by the resonant frequency of the transformer 44 and the time constant of the circuit including condenser 48. The output current and voltage of the transistor oscillator takes the form of relatively short pulses; the amplitude of which may be varied by adjustment of the bias current in the input circuit. The output voltage of the oscillator is transformed to a relatively high value by an appropriate turns ratio between a secondary winding 52 and the primary winding 42 of the transformer 44. This value of high voltage is accurately adjusted by the position of the movable contact on the potentiometer resistor 32 of the voltage divider.

The high voltage developed by the secondary winding 52 is rectified by the diode 54 and applied to the elec-

trodes of the photomultiplier tube 14. For this purpose one terminal of the secondary winding 52 is connected to the plate electrode of diode 54 and the cathode electrode thereof is connected to ground. The heater filament 56 of the diode 54 is energized by connection between the regulated voltage conductor 28 in series with resistor 58 and ground. It is noted that with the cathode of diode 54 connected to ground the high voltage developed by the secondary winding 52 is of negative polarity, referred to ground potential. This negative voltage is derived from the other terminal of the secondary winding 52 and applied through high voltage conductor 60 and the variable resistor 62 and current limiting resistor 64a to the photocathode 66. A filter condenser 61 is connected between the high voltage conductor 60 and ground. The variable resistor 62 affords an additional adjustment of the high voltage applied to the electrodes of the photomultiplier tube. This negative high voltage is also applied from the movable contact of variable resistor 62 across the voltage divider comprising the series resistors 68a, 68b, 68c . . . and 68j, which are suitably of equal resistance value. Plural stages of current multiplication are provided in the photomultiplier tube by the successive dynodes connected respectively through the current limiting resistors 64b, 64c, 64d . . . and 64j to the corresponding junctions of the voltage divider resistors. The anode 70 of the photomultiplier tube is connected through the load resistor 72 and thence conductor 57 and heater filament 56 to ground. The load resistor 72 develops a control voltage corresponding to the intensity of light incident upon the photocathode 66 for the control circuit to be described presently.

The control amplifier comprises an electron tube 74 of the low voltage space-charge grid type suitably a 12K5, currently available from the Tung Sol Electric Corporation. The control voltage developed across the load resistor 72 is included in the input circuit of the tube 74 which extends between the control grid and cathode. The control relay 16 having an energizing winding 76 is included in the output circuit of this tube which extends between the plate and the cathode through the conductors 78 and 80, the selector switch 20, and the battery 10 to ground. A condenser 75 is connected between plate and control grid to provide a degenerative path for any alternating voltage reaching the control grid and thus prevents response of the control relay to sudden changes of grid voltage. The space-charge grid of the tube 74 is connected through the conductors 82 and 80, switch 20 to the battery 10. The bias conditions on the tube 74 are such that the tube is conductive in the absence of a control voltage across load resistor 72.

To provide an upper beam energizing circuit for the headlamps the control relay 16 includes a movable contact 84, normally closed by a bias spring against the lower beam contact 86, which is displaced by the energization of the relay coil 76 against the upper beam contact 88. This upper beam contact 88 is connected through the variable dim sensitivity resistor 90 and conductor 92 to an intermediate tap 93 between the voltage divider resistors 68h and 68i. The movable contact 84 is connected to ground through conductor 94 and the manually operated dimmer switch 96 and through the energizing coil 100 of power relay 18. Thus the variable resistor 90 is connected in parallel with the voltage divider resistors 68i and 68j. The power relay 18 includes a movable contact 102 spring biased into engagement with the upper beam contact 104 to complete a circuit from the battery 10 through the upper beam headlamp filament 106. This relay also includes a lower beam contact 108 for energizing the lower beam headlamp filament 110 from the battery 10 when the relay winding 100 is energized. To provide a lower beam energizing circuit for the headlamps, the control relay 16 when de-energized causes the movable contact 84 to engage the

lower beam contact 86 which is connected through conductors 78 and 80 and selector switch 20 to the battery 10. The movable contact 84, as previously described, is connected through the energizing coil 100 of the power relay to ground and thus the power relay is energized. Accordingly, the movable contact 102 is displaced into engagement with the lower beam contact 108 completing circuit from the battery 10 through the lower beam headlamp filament 110 to ground. In this condition the control relay also disconnects the dim sensitivity resistor 90 from the tap 93 between the voltage divider resistors 68h and 68i. A resistor 112 is connected across the terminals of the energizing coil 100 of the power relay to absorb the inductive surge which results from de-energization of this relay by opening control relay contacts 84 and 86.

In order to provide for manual overriding control of the automatic control circuit, the manual switch 114 is connected from ground through resistor 118 to one terminal of the control relay coil 76, the other terminal of which is connected through conductors 78 and 80, and selector switch 20 to the battery 10. Accordingly, closure of this switch energizes the control relay regardless of the conductive state of tube 74 and displaces movable contact 84 to engagement with upper beam contact 88. This de-energizes the power relay coil 100 permitting the spring biased movable contact 102 to engage the upper beam contact 104 and complete the energizing circuit for the upper beam headlamp filament 106.

To provide for complete manual control of the headlamp beam selection by the dimmer switch 96, the automatic control circuit is de-energized by opening the manual selector switch 20. With the dimmer switch movable contact 98 closed against the lower beam contact 118, a circuit is completed from the battery 10 through these contacts and through the power relay coil 100. This, of course, pulls the movable contact 102 into engagement with the lower beam contact 108 and energizes the lower beam headlamp filament 110. When the movable contact 98 is displaced against fixed contact 99, the energizing circuit for the power relay coil 100 is interrupted and the movable contact 102 engages fixed contact 104 energizing the upper beam headlamp filament 106.

In operation of the automatic control system, the selector switch 20 is closed to apply the battery voltage to the voltage regulator 22 and the regulated voltage developed on the conductor 28 is applied across the voltage divider including potentiometer resistor 32, a portion of which, with the resistor 34, is connected in the input bias circuit of the transistor oscillator 36. The oscillator develops, in the secondary winding 52 of transformer 44, a high voltage having a value determined by the bias current value. This high voltage is rectified by diode 54 and applied across the electrodes of the photomultiplier tube 14. Since the photomultiplier tube has a sensitivity to incident light dependent upon the applied high voltage, the overall sensitivity may be adjusted at a low voltage level by the movable contact on the potentiometer resistor 32. In the absence of light on the photomultiplier tube, the control voltage across load resistor 72 is of such value that the electron tube 74 is sufficiently conductive to energize the control relay 16 and displace the movable contact 84 against the fixed contact 88. Accordingly, the power relay 16 is de-energized and an energizing circuit is completed there-through for the upper beam headlamp filament 106.

With the control relay 16 energized, the movable contact 84 connects the dim sensitivity resistor in parallel with the voltage divider resistors 68i and 68j. Suitably the voltage divider resistors 68a, 68b, etc. are all of the same value and when resistor 90 is disconnected from the circuit, an equal voltage rise is applied between successive dynodes. Accordingly, the secondary emission ratio or multiplication factor p of all dynodes is the same

value and for n dynodes or stages the overall current multiplication is proportional to p^n . Since current multiplication and hence sensitivity of the tube is an exponential function of the number of dynodes, a substantial sensitivity change may be accomplished by effectively reducing the number of dynodes. This is achieved by connecting the variable resistor 90 across the resistors 68i and 68j to reduce the voltage and hence the value of the multiplication factor of the corresponding dynodes. The resistor 90 is suitably of the same order of magnitude as the sum of resistors 68i and 68j and, accordingly, its parallel connection results in a high percentage voltage decrease across resistors 68i and 68j, causing a substantial decrease in the multiplication factor of the corresponding dynodes. At the same time, a small percentage voltage increase occurs across the remaining resistors 68a, 68b, 68c, 68d, 68e, 68f, 68g, and 68h causing only slight change in the multiplication factor of the corresponding dynodes. As a result, the connection of the parallel resistor 90 produces a marked reduction in the sensitivity of the photomultiplier tube. Since the resistor 90 is connected across only resistors 68i and 68j of the voltage divider, the switching of sensitivity is accomplished at low voltage. The value of resistor 90 is adjusted to obtain a sensitivity change ratio of about ten to one. The adjusted value of resistance 90 in combination with the adjusted voltage value of potentiometer resistor 32 establishes a predetermined value of light intensity on the photocell required to develop the control voltage necessary to render tube 74 nonconductive.

Upon the occurrence of this predetermined light intensity on the photomultiplier tube the control voltage developed across load resistor 72 causes electron tube 74 to become non-conductive. Thus the control relay 16 is de-energized and the movable contact 84 engages fixed contact 86. This interrupts the dim sensitivity circuit disconnecting resistor 90 from the voltage divider resistors 68i and 68j. This increases the sensitivity of the photomultiplier tube so that a lesser intensity of incident light will develop sufficient control voltage to maintain the control relay in the lower beam position even though the incident light from an oncoming vehicle is reduced by headlamp switching. At the same time, the control relay contacts 84 and 86 complete an energizing circuit for the power relay coil 100 and the movable contact 102 engages fixed contact 108 to complete the energizing circuit for the lower beam headlamp filament 110.

As previously described, manual override control is provided by closing switch 114 to energize the control relay regardless of the conductive condition of tube 74. Such energization of the control relay will cause de-energization of the power relay permitting contacts 102 and 104 to close and energize the upper beam headlamp filament 106.

Complete manual operation of the headlamps is afforded by opening selector switch 20 and manipulation of the dimmer switch 96. It will be noted that the circuit arrangement permits removal of the automatic control circuit from the vehicle for servicing while leaving the manual control system entirely operative. Disconnection for removal may be effected at either terminal of switch 20. With contact 98 closed against fixed contact 118, the power relay 100 is energized and the lower beam filament 110 is energized. With the contact 98 in engagement with fixed contact 99, the power relay is de-energized and the upper beam filament is energized.

Although the invention has been described with respect to a particular embodiment, such description is not to be construed in a limiting sense. Numerous modifications and variations within the spirit and scope of the invention will now occur to those skilled in the art. For a definition of the invention, reference is made to the appended claims.

We claim:

1. A headlamp control system comprising a photo-

multiplier tube of the type including a photocathode, a plurality of dynodes and an anode, a high voltage source, a voltage divider connected between the photocathode and the anode and across the voltage source, plural taps on the voltage divider connected respectively with said dynodes, a load impedance connected with the anode for developing a control voltage, control means including a relay connected with the load impedance and responsive to a predetermined value of control voltage for actuating said relay, a headlamp switching circuit, a photomultiplier tube sensitivity circuit including a resistor connectible in parallel with a portion of the voltage divider, and switching means actuated by said relay for alternately completing said sensitivity circuit and said headlamp switching circuit.

2. A headlamp control system comprising a photomultiplier tube of the type including a photocathode, a plurality of dynodes and an anode, a high voltage source, a resistive voltage divider connected between the photocathode and the anode and across the voltage source, plural taps on the voltage divider connected respectively with said dynodes, a load impedance connected with the anode for developing a control voltage, control means including a relay connected with the load impedance and responsive to a predetermined value of control voltage for actuating said relay, said relay including a movable contact and a pair of fixed contacts, a low voltage source, a headlamp switching circuit including a power relay having an energizing winding connected between one terminal of the low voltage source and said movable contact, one of said fixed contacts being connected to the other terminal of said low voltage source whereby actuation of the control relay in one sense causes operation of the power relay to switch the headlamps, a sensitivity control resistor connected between an intermediate point on said voltage divider and the other of said fixed contacts whereby actuation of the control relay in the other sense reduces the voltage applied to certain of said dynodes and reduces the sensitivity of the photomultiplier tube.

3. A headlamp control system comprising a photomultiplier tube of the type including a photocathode, a plurality of dynodes and an anode, a low voltage direct current source, a transistor oscillator energized from the voltage source and having an input circuit and an output circuit, said output circuit including a transformer connected across a resistive voltage divider connected between the photocathode and the anode for supplying a high value energizing voltage thereto, an adjustable voltage divider coupling the low voltage source to said input circuit whereby the high voltage across the resistive voltage divider may be adjusted, plural taps on the resistive voltage divider connected respectively with said dynodes, a load impedance connected with said anode for developing a control voltage control means including a relay connected with the load impedance and responsive to a predetermined value of control voltage for actuating said relay, a headlamp switching circuit, a sensitivity circuit including a resistor connectible in parallel with a portion of said resistive voltage divider, and switching means actuated by said relay for alternately completing said sensitivity circuit and said headlamp switching circuit.

4. A headlamp control system comprising a photomultiplier tube of the type including a photocathode, a plurality of dynodes and an anode, a low voltage direct current source, a transistor oscillator energized from the voltage source and having an input circuit and an output circuit, said output circuit including a transformer connected across a resistive voltage divider and between the photocathode and the anode for supplying a high value energizing voltage thereto, an adjustable voltage divider coupling the low voltage source to said input circuit whereby the high voltage across the resistive voltage divider may be adjusted, plural taps on the resistive voltage divider connected respectively with said dynodes, a

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load impedance connected with said anode for developing a control voltage, control means including a relay connected with the load impedance and responsive to a predetermined value of control voltage for actuating said relay, said control relay including a movable contact and a pair of fixed contacts, a headlamp switching circuit including a power relay having an energizing winding connected between one terminal of the low voltage source and said movable contact, one of said fixed contacts being connected to the other terminal of said low voltage source, a sensitivity control resistor connected between an intermediate point on said resistive voltage divider and the other of said fixed contacts whereby actuation of said control relay between the pair of fixed contacts alternately causes operation of the power relay to switch the headlamps and causes connection of said resistor to reduce the voltage applied to certain of said dynodes and thereby reduces the sensitivity of the photomultiplier tube.

5. A headlamp control circuit comprising light responsive device for producing a control voltage corresponding to the incident light intensity and having a sensitivity to variations thereof dependent upon the value of energizing voltage applied to the device, control means connected with said device and responsive to a predetermined value of said control voltage for switching a headlamp circuit, a low voltage direct current source, a transistor oscillator energized from the voltage source and having an input circuit and an output circuit, said output circuit including a transformer connected with said device for supplying a high value energizing voltage thereto, an adjustable voltage divider coupling the low voltage source to said input circuit whereby the sensitivity of the device and the incident light required to produce the predetermined value of control voltage may be established by adjustment of the low voltage applied to the oscillator.

6. A headlamp control circuit comprising a photomultiplier tube for producing a control voltage corresponding

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to the incident light intensity and having a sensitivity to variations thereof dependent upon the value of energizing voltage applied to the electrodes of said tube, an output impedance connected with said tube for developing a control voltage, control means connected with said impedance and responsive to a predetermined value of said control voltage for switching a headlamp circuit, a low voltage direct current source, a transistor oscillator including a transistor having emitter, collector and base electrodes, a voltage regulator connected across said low voltage source, a voltage divider including a potentiometer resistor connected across said regulator, an input circuit for said oscillator extending between said emitter and base electrodes and including said potentiometer resistor, an output circuit for said oscillator extending between the emitter and collector electrodes and including said potentiometer resistor and the primary winding of a transformer, a feedback winding on said transformer and a blocking condenser serially connected between said emitter and base electrodes, a secondary winding on said transformer connected with a rectifier across the electrodes of said photomultiplier tube whereby the sensitivity of the photomultiplier tube and the incident light required to produce the predetermined value of control voltage may be established by adjustment of the potentiometer resistor.

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