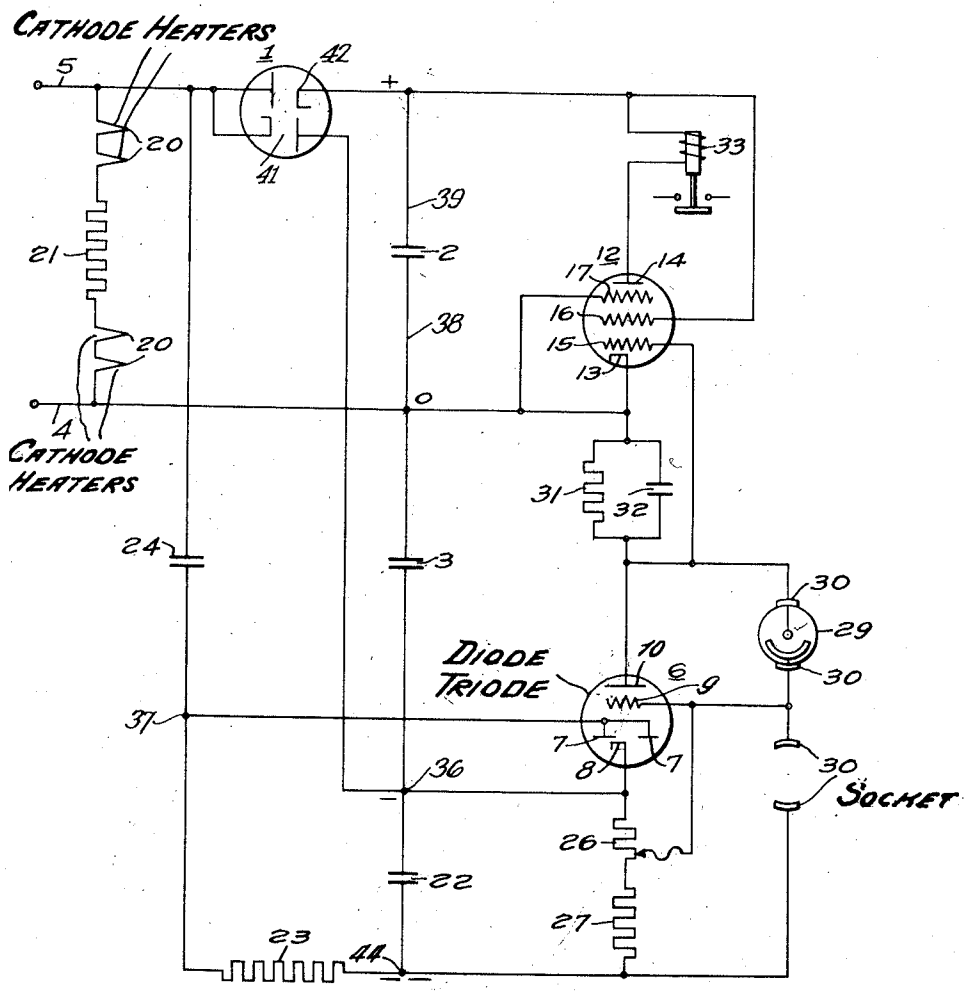
March 30, 1937. B. E. LENEHAN 2,075,120

ELECTRONIC APPARATUS

Filed Feb. 23, 1935



WITNESSES:

E. A. McCloskey.

Geo. O. Harrison.

INVENTOR

Bernard E. Lenehan.

BY

ATTORNEY

Patented Mar. 30, 1937

2,075,120

UNITED STATES PATENT OFFICE

2,075,120

ELECTRONIC APPARATUS

Bernard E. Lenehan, Bloomfield, N. J., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application February 23, 1935, Serial No. 7,929

15 Claims. (Cl. 250—41.5)

My invention relates to electronic apparatus and particularly to light relays as used for counting and sorting, the photoelectric control of doors and traffic signals, the control of web-working machinery and similar applications. In its more specific aspects, my invention relates to light relays of the type consisting of a photo-responsive element, such as a photo-tube, an electronic amplifier connected to respond to a variation of electric condition of the photo-tube, and an electromagnetic relay responsive to the output of the amplifier. In its more general aspects, the invention provides novel features of general utility in connection with rectifying apparatus, amplifiers and light relays.

In one form of light relay, as heretofore constructed, a single triode or pentode has been used for amplification, and a voltage doubler has been provided for supplying the plate voltage of this tube. Such a light relay is simple and compact, but for many applications, particularly where the distance between the light source and photo-tube is great, is not sufficiently sensitive to insure positive operation with commercial forms of light sources. If the overall amplification of the relay is increased by adding tubes, the additional complications usually result in a considerable sacrifice of simplicity and compactness.

It is an object of my invention to provide a novel amplifying circuit for light relays of the type mentioned above.

Another object of my invention is to provide a novel super-sensitive light relay.

Other objects of my invention will become evident from the following detailed description taken in conjunction with the accompanying drawing, in which the single figure is a diagrammatic view of a light relay embodying my invention.

Referring to the drawing in detail, a suitable rectifying device 1 having two independent anode-cathode discharge paths or rectifying elements 41 and 42, is provided for charging a pair of condensers 2 and 3. The condensers 2 and 3 each have one terminal connected to a conductor 4 of an alternating-current supply circuit, and the remaining terminal connected with an electrode of the rectifying device 1. The remaining two electrodes of the device 1 are connected to the remaining conductor 5 of the supply circuit, in a well known manner, to form a voltage doubler.

The condenser 3 is connected to supply plate voltage to a diode-triode type vacuum tube 6. This tube preferably is of the so-called duplex-diode high amplification type, that is, is provided with a pair of diode plates 7, which cooperate with the cathode 8 of the tube to form a diode or rectifier. The usual grid 9 and plate 10 are arranged to cooperate with the cathode 8 to form a triode having a high amplification factor.

The condenser 2 is connected to supply plate voltage to a pentode 12. The pentode 12 is of the usual type having a cathode 13, an anode or plate 14, a control grid 15, a screen 16 interposed between the control grid 15 and the plate 14, and a suppressor 17, interposed between the screen 16 and the plate 14. The screen 16 is connected to a suitable positive source such as the positive terminal of the condenser 2, and serves the function of reducing the plate voltage required and rendering the plate current substantially independent of plate voltage. The suppressor 17 is connected to the cathode 13, in the usual manner, to reduce secondary emission from the plate 14.

The three tubes 1, 6 and 12 are all preferably of the so-called "hard" or highly evacuated type, and are all provided with insulated heaters 20 for the cathodes. The heaters 20 are built within the cathodes in the usual manner, but, for simplicity of illustration, are shown separate from the tubes, and connected in a series circuit to the supply conductors 4 and 5. A resistor 21 is provided for absorbing the excess of supply voltage above that necessary for the heaters 20.

In accordance with my invention, the diode circuit of the tube 6 is non-conductively coupled to the alternating-current supply circuit 4, 5 in such manner that an alternating-current voltage is applied between the diode plates 7 and the cathode 8, but a conductive connection between the cathode 8 and upper conductor 5 of the supply circuit is avoided. To this end, a condenser 22 and a resistor 23 are connected between the diode circuit of the tube 6, and an alternating-current circuit consisting of the condenser 3, the condenser 22, resistor 23, and a blocking condenser 24. The condensers 3 and 22, pass alternating-current in the usual manner, notwithstanding that they accumulate a direct-current charge in the connection shown. The condenser 24 serves to prevent the condenser 22 from discharging through the alternating-current source (not shown) when the light relay is in operation, and accordingly permits the condenser 22 to accumulate a direct current charge, as indicated by the minus signs.

A high-resistance potentiometer consisting of an adjustable resistor 26 and a fixed leak re-

sistor 27 is connected across the condenser 22 for supplying an adjustable bias to the grid 9 of the tube 6. A photo-tube 29, which may be either of the highly exhausted or of the gas-filled type, is connected to the grid 9 for controlling the potential of the latter. The photo-tube 29 may be connected between the grid 9 and plate 10 of the tube 6, as shown, in order to obtain relay operation when the supply of light to the photo-tube is interrupted, or may alternatively be connected between the resistor 27 and the grid 9, to obtain relay operation when the photo-tube 29 is illuminated. A pair of sockets 30 are permanently connected in the circuit to permit either connection.

A plate resistor 31, of suitable resistance value, is connected in the plate circuit of the triode 6, and a condenser 32 is connected in parallel to the plate resistor 31 to provide a short time delay in the operation of the light relay.

The plate 10 of the tube 6 is connected to the control grid 15 of the pentode 12, and the plate 14 of the pentode 12 is connected in series with a suitable electromagnetic contactor 33.

It will be noted that the mutual impedance relationship of condenser 22 and resistor 23, mentioned above, leaves one degree of freedom in the design of these elements, inasmuch as the proper total impedance drop across both elements in series can be secured with various relationships of capacitance and resistance in the elements themselves. This degree of freedom is preferably taken up in making the time constant of the grid circuit of the triode 6 equal to the time constant of the plate circuit of the triode 6 for the value of plate resistance existing when the photo-tube 29 is normally illuminated. In this way, if a sudden decrease of line voltage occurs while the device is in operation, the bias voltage and the plate voltage of the triode 6 decrease exponentially with respect to time, but maintain the same ratio to each other. The change of plate current of the triode 6, under these conditions is negligible, and a false operation is avoided.

The resistors 23, 27 and 26 and the condenser 22 may be considered as a single mutual impedance having a first terminal 36 connected to the cathode 8 and a second terminal 37 connected to the diode plates 7. The condenser 3 is connected between the first terminal 36 and a first conductor 4 of the supply circuit. The condenser 24 is connected between the second terminal 37 and a second conductor 5 of the supply circuit, and the rectifying element 41 of rectifier 1 is connected between the first terminal 36 and the second conductor 5. The condenser 2 has a connection 38 to the first conductor 4, and a second connection 39 to the rectifying element 42 of the rectifier 1.

The operation of the above-described apparatus may be set forth as follows: Upon connection of the supply conductors 4 and 5 to a suitable alternating-current source, rectified current flows through the rectifying device 1, and the condensers 2 and 3 acquire direct-current charges in the directions indicated by the plus, zero and minus signs. The voltage developed across the two condensers 2 and 3 in series will vary from a maximum of twice the crest voltage of the alternating-current source at no load, to a considerably lower value under load, depending upon the load current drawn and the capacitance of the condensers. For a 110 volt alternating-current source, this voltage under ordinary load conditions may be of the order of 200 volts, for example.

A circuit for energizing the diode elements 7, 8 of the tube 6 from the alternating current source 4, 5, may be traced as follows: From the supply conductor 4 through the condenser 3, thence in two parallel paths through the condenser 22 and through the resistors 26 and 27, respectively, to the lower junction point 44; from the junction point 44 as a single circuit through the resistor 23 and condenser 24 to the supply conductor 5. The alternating voltage of the supply circuit 4, 5 being impressed upon the circuit just traced, impedance voltage drops, or IZ drops, are set up in the various condensers and resistors, in accordance with the usual laws of voltage distribution in an impedance network. The impedance voltage drop appearing between the first terminal 36 and the second terminal 37 is directly impressed upon the diode elements 7, 8 of the tube 6, because of the fact that the impedance elements 22, 26, 27 and 23 are common to both the input circuit of the diode consisting of the electrodes 7 and 8 of tube 6 and the energizing circuit traced above. The portion of the impedance network consisting of the condenser 22 and resistors 23, 26 and 27, accordingly, may be regarded as a single mutual impedance, as mentioned above. Because of the alternating impedance voltage drop impressed upon the diode electrodes 7 and 8, and because of the unidirectional conducting character of the discharge space between these electrodes, a pulsating unidirectional current flows in the diode circuit until the condenser 22 is charged to the peak or crest value of the impedance drop. The charge accumulated by the condenser 22 in this way provides a suitable bias voltage for the tube 6, and also a photo-tube voltage for the photo-tube 29, when the latter is mounted in the lower socket 30.

It will be noted that the connection described above provides a direct-current voltage having an overall no-load maximum greater than twice the peak value of the impressed alternating-current voltage. This high direct-current voltage can be obtained between the upper terminal of condenser 2 and the lower terminal of condenser 22. It is also possible to obtain a rectified half wave voltage greater than the peak value of the impressed alternating-current voltage. This voltage may be obtained between the conductor 4 and the lower terminal of the condenser 22.

In obtaining these high voltages, the condensers 3 and 24 provide direct-current insulation separating the condenser 22 from the supply circuit 4, 5. Because of this insulation, with reference to direct-current charge, the direct current voltage accumulated on the condenser 22 is added to the direct-current voltage on the condensers 2 and 3, producing a total direct-current voltage, between the connection 39 and the junction point 44, which may be greater than twice the crest voltage of the alternating-current supply circuit 4, 5, under conditions of no-load. In prior art voltage doublers and similar apparatus, so far as I am aware, it has not been practical to obtain no-load direct-current voltages higher than twice the crest value of the alternating-current voltage supply, except by the use of transformers, or equivalent.

Inasmuch as the plate circuit of the pentode 12, the plate circuit of the triode 6 and the grid circuit of the triode 6 are supplied from separate condensers 2, 3 and 22 respectively, and the cou-

pling of these circuits is negligible, regenerative effects in both tubes are avoided.

Assuming that the photo-tube **29** is mounted in the upper socket **30**, as shown, and is being constantly illuminated from a light-source (not shown), a photo-electric current flows through the tube **29** tending to change the potential of the grid **9** from negative to positive. The circuit is preferably so designed that the grid **9** is at a potential close to the "cut-off" point of the tube **6**, under these circumstances. The tube **6** accordingly passes a small plate current which flows through the plate resistor **31**, setting up an IR drop therein which biases the control grid **15** of the pentode **12** negatively. The plate current of the pentode **12** may be small or zero under these conditions.

If the supply of light to the photo-tube **29** is interrupted, the latter becomes non-conducting, and the potential of the grid **9** becomes sufficiently negative to interrupt the plate current of the tube **6**. Upon interruption of the plate current of tube **6**, the charge upon the condenser **32** dissipates through the resistor **31**, and the negative voltage of the grid **15** disappears, thereby allowing a heavy plate current to flow through the coil of contactor **33** to effect operation of the latter.

By choosing a condenser **32** of suitable capacitance, the time delay of the light relay may be varied as desired.

I do not intend that the present invention shall be restricted to the specific structural details, arrangement of parts or circuit connections herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of my invention. I desire, therefore, that only such limitations shall be imposed as are indicated in the appended claims.

I claim as my invention:

1. In apparatus for increasing and rectifying the voltage of an alternating-current source, an alternating-current supply circuit having a first conductor and a second conductor, a mutual impedance having a first terminal and a second terminal, a condenser connected between said first conductor and said first terminal, a condenser connected between said second conductor and said second terminal, and rectifying apparatus including a pair of rectifying elements having electrodes of opposite polarity connected to said first terminal, one of said rectifying elements having its remaining electrode connected to said second conductor, and the other of said rectifying elements having its remaining electrode connected to said second terminal, whereby the maximum direct-current voltage available between said first conductor and said second terminal exceeds the instantaneous maximum voltage of said supply circuit.

2. In apparatus for increasing and rectifying the voltage of an alternating-current source, an alternating-current supply circuit, an impedance including a capacitive element, a pair of condensers, a series circuit connecting said condensers and said impedance to said supply circuit, said impedance being included between said condensers, and rectifying apparatus including a rectifying element connected across at least a part of said impedance, said part including said capacitive element, and a rectifying element connected across one of said condensers and said part, the relative direction of said rectifying elements being such that unlike electrodes thereof are conductively connected together at said mutual impedance.

3. In apparatus for increasing and rectifying the voltage of said alternating-current source, an alternating-current supply circuit having a first conductor and a second conductor, a mutual impedance having a first terminal and a second terminal, a condenser connected between said first conductor and said first terminal, a condenser connected between said second conductor and said second terminal, a condenser having a connection to said first conductor and having a second connection, and rectifying apparatus including a first rectifying element connected across said mutual impedance, a second rectifying element connected between said first terminal and said second conductor, and a third rectifying element connected between said second connection and said second conductor, said first and second rectifying elements having electrodes of unlike polarity connected to said first terminal, and said second and third rectifying elements having electrodes of unlike polarity connected to said second conductor, whereby the maximum no-load direct-current voltage between said second terminal and said second connection exceeds twice the maximum instantaneous voltage of said supply circuit.

4. The combination defined in claim 3 in which the mutual impedance consists at least partially of capacitance.

5. The combination defined in claim 3 in which the mutual impedance consists of capacitance and resistance.

6. The combination defined in claim 3 in which the rectifying elements are of the hot-cathode type having insulated heaters, and in which the heaters are connected in a series energizing circuit.

7. In electronic apparatus energizable from an alternating-current source, an alternating-current supply circuit, a mutual impedance, a first condenser, a second condenser, a series circuit connecting said condensers and said mutual impedance to said supply circuit, said mutual impedance being connected between said condensers, an electric discharge device having a rectifying discharge path and a controlled discharge path electrically connected at their cathode ends, said device including a cathode, an anode and a control element for said controlled discharge path and a diode plate for said rectifying discharge path, a connection from said cathode to said series circuit at a point between said mutual impedance and said first condenser, a connection from said diode plate to said series circuit at a point between said mutual impedance and said second condenser, a connection from said mutual impedance to said control element, a connection from said anode to said supply circuit on the side thereof connected to said first condenser, a rectifier, and a connection from said cathode to said supply circuit on the side thereof connected to said second condenser, said last-mentioned connection including said rectifier, the direction of rectification thereof being such as to pass the current supply of said controlled discharge path.

8. The combination defined in claim 7 in which the mutual impedance consists at least partially of capacitance.

9. The combination defined in claim 7 in which the mutual impedance consists of capacitance and resistance.

10. The combination defined in claim 7 in which the connection from the mutual impedance to the control element includes a high-resistance potentiometer connected across at least part of the mutual impedance.

11. In a light relay energizable from an alternating-current source, an alternating-current supply circuit including a reference conductor, a voltage doubler comprising a pair of condensers and rectifying means for charging one of said condensers positively and the other negatively as compared to said reference conductor, a pair of coupled amplifying discharge devices energized from said condensers, one of said discharge devices having a diode discharge path, means for producing a biasing voltage more negative than said negatively charged condenser comprising a mutual impedance connected in parallel to said diode discharge path and capacitance means connecting said mutual impedance in insulated relationship to said supply circuit, and a photo-electric element for controlling said amplifying discharge devices.

12. The combination defined in claim 11 in which the amplifying discharge device having the diode path is connected to the negatively charged condenser and the other amplifying device is connected to the positively charged condenser.

13. The combination defined in claim 11 in which the amplifying discharge device having the diode path is connected to the negatively charged condenser and the other amplifying device is connected to the positively charged condenser, and in which the output circuit of the amplifying device having the diode path is directly coupled to the input circuit of the other discharge device.

14. The combination defined in claim 11 in which the amplifying device having the diode path is of the diode-triode type, and the remaining amplifying device is a pentode.

15. In a direct-coupled amplifying unit energizable from an alternating-current source, a first-stage electronic device having a cathode, an anode and a control electrode, a second-stage amplifying device having a cathode, an anode and a control electrode, direct-current supply means for said devices comprising a first terminal, a second terminal, a third terminal, a fourth terminal and rectifier and condenser means energized from said source for maintaining progressively more negative direct-current voltages on said first, second, third and fourth terminals, means connecting said first terminal to said anode of said second-stage device, a direct connection of minimum impedance from said second terminal to the cathode of said second-stage device, a direct connection of minimum impedance from said third terminal to the cathode of said first-stage device, a comparatively high-resistance coupling circuit connecting said second terminal to said anode of said first-stage device, a connection from said coupling circuit to said control electrode of said second-stage device and a connection from said fourth terminal to said control electrode of said first-stage device, whereby regenerative effects in said devices are substantially avoided.

BERNARD E. LENEHAN.