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LOW VOLTAGE OSCILLATORY CIRCUIT

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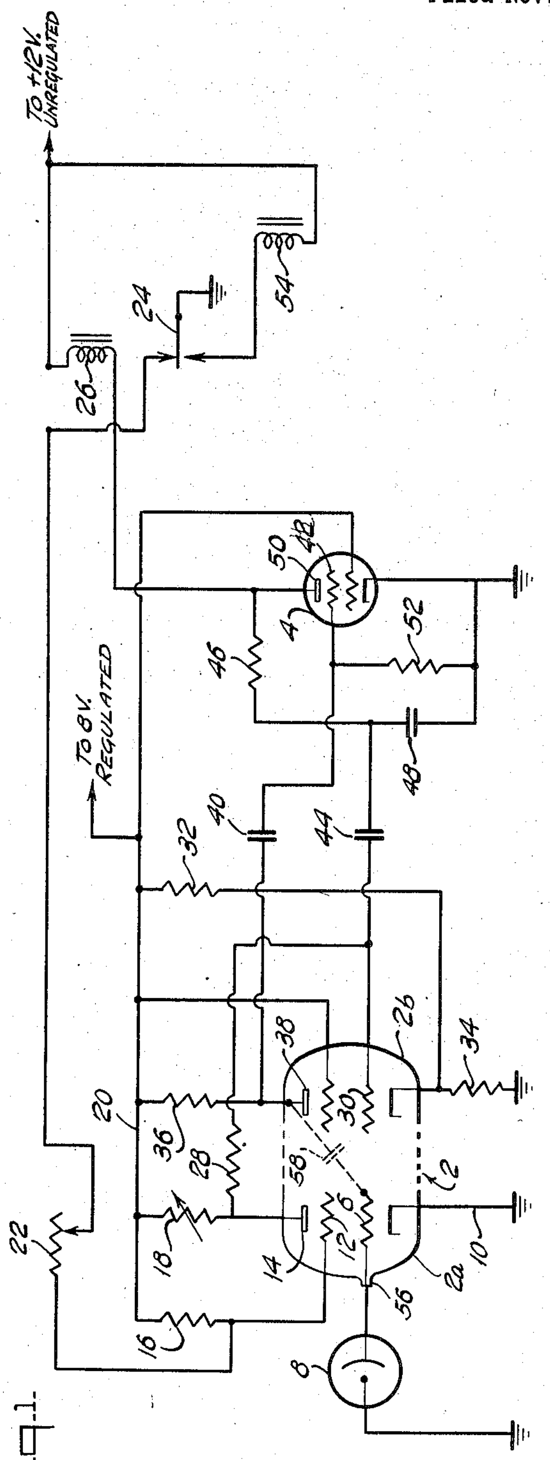

Fig. 1.

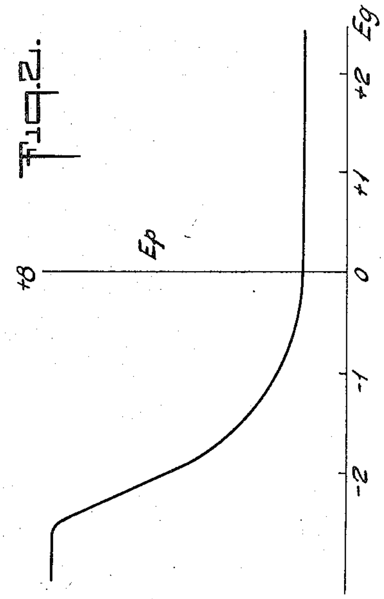

Fig. 2.

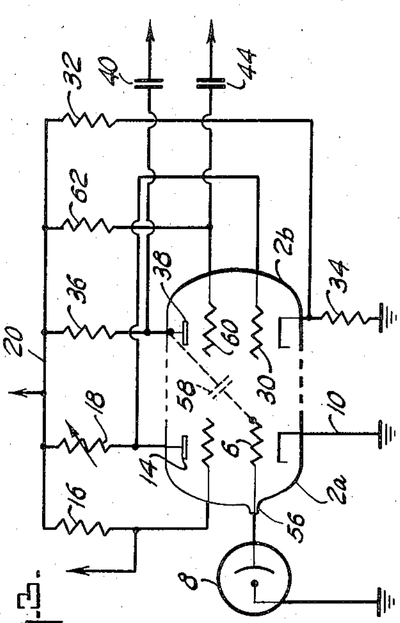

Fig. 3.

INVENTOR
CARL E. ATKINS
BY
Eyre, Mann & Burrows
ATTORNEYS

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LOW VOLTAGE OSCILLATORY CIRCUIT

Carl E. Atkins, Bloomfield, N. J., assignor to Tung-Sol Electric Inc., a corporation of Delaware

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10 Claims. (Cl. 317—130)

The present invention relates to a novel low voltage oscillatory circuit suitable for use as a multivibrator and to a light responsive circuit incorporating the new oscillatory circuit.

As the new oscillatory circuit, while of general application, is particularly adapted for use in the control of automobile headlamps in response to incidence of light, it will be described with reference to such application and particularly with reference to the type of light responsive system disclosed and claimed in my prior pending applications Serial No. 433,959, filed June 2, 1954, and Serial No. 547,508, filed November 17, 1955, over which the light responsive circuit of the present invention is an important improvement. Each of the circuits of the said prior applications comprises in general a photoelectric tube, preferably a diode, which when subjected to light causes increase in current through an electronic multi-element tube (called an electrometer tube), an oscillatory circuit coupled to the electrometer tube through a phase inverter and quiescent except when light is incident on the photocathode of the photoelectric tube and a relay control tube connected to the oscillatory circuit to receive controlling pulses therefrom when the photoelectric tube is subjcted to light, the relay control tube being normally conducting to hold energized in its plate circuit a sensitive relay which, upon release of its armature, closes contacts controlling the circuit of a power relay. Five electronic tubes, or tube sections where double tubes are employed, are required in addition to the photoelectric tube, in each of the circuits of my said prior applications. These five comprise the electrometer tube or tube section, the phase inverting tube or tube section, two tube sections of a double triode connected as a multivibrator and the relay control tube.

In the new light responsive circuit incorporating the novel oscillatory circuit of the present invention only three electronic tubes or tube sections are required as contrasted to the five required in my prior circuits. The need for a phase inverter tube section has been obviated and the relay control tube serves not only to control the sensitive relay but also as one of the two tubes of the new oscillatory circuit.

In the new oscillatory circuit, unlike the usual multivibrator circuit, oscillations are initiated by application of negative potential to the control grid of the first of the two tubes or tube sections and quenched by application of positive potential to such grid. Hence in the light responsive circuit, the potential of the anode of the electrometer tube which decreases with increase in intensity of light incident on the photocathode and increases when the intensity of the incident light decreases, can be used directly as the control potential of the oscillatory circuit to initiate oscillation thereof when light of a predetermined intensity is incident on the photocathode and to quench the oscillation of the oscillatory circuit when the intensity of incident light reduces to a predetermined value.

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The new oscillatory circuit, as above indicated, includes two electronic tubes, preferably tetrodes each of which, in the quiescent state, are conducting. Relatively low operating potential of the order of 8 to 15 volts is applied to the anode of the first tube through a dropping resistor and to the anode of the second tube, preferably through an inductor. In the particular application of the circuit to the control of the dimming switch of an automobile the inductor is the sensitive relay hereinbefore mentioned in connection with the description of the circuits of the said prior applications and the source of voltage is the car carried battery of nominally 12 volts. When the oscillatory circuit is quiescent the control grid potential of the first tube is such that the tube passes maximum current and hence any increase in positive potential applied to the control grid can not increase the anode current. A decrease in control grid potential will, however, reduce the current through this tube and cause an increase in potential at the anode thereof. The anodes and control grids of the two tubes of the oscillatory circuit are so interconnected that increase in potential at the anode of the first tube will initiate oscillations of the circuit. Oscillations will cease when the control grid of the first tube is raised sufficiently to cause the tube to again become saturated.

Preferably the second tube of the oscillatory circuit, the relay control tube, is of the space charge grid type, the first grid being maintained at a positive potential of say 8 volts and the second grid serving as the control grid. A large bias resistor is provided for the control grid to cause the potential of the grid to be driven negative by the self-rectifying properties of the grid cathode circuit when positive pulses from the anode of the first tube are impressed upon the control grid of the second tube. Thus during oscillation of the steady current through the second tube is gradually reduced to release the sensitive relay whereas pulses of relatively large magnitude due to the inductive effect of the relay winding appear at the anode of the second tube to be transmitted back to the control grid of the first tube to maintain the circuit in oscillation.

For a better understanding of the oscillatory circuit and of the new light responsive circuit incorporating the same reference may be had to the accompanying drawing of which:

Fig. 1 is a circuit diagram of a light responsive circuit embodying the invention;

Fig. 2 is a graph explanatory of the operation of the first tube of the oscillatory circuit; and

Fig. 3 is a diagram illustrating an alternative arrangement for part of the circuit of Fig. 1.

In Fig. 1 the light responsive circuit of the invention is shown as including a double tetrode **2** the first half **2*a*** of which operates as the electrometer portion of the circuit and the second half **2*b*** of which operates as the first tube of the oscillatory circuit, and a relay control tube **4** which serves also as the second tube of the oscillatory circuit. The control grid **6** of the electrometer portion **2*a*** of tube **2** is connected to the photocathode of a photoelectric tube **8**, the anode of which is grounded. The cathode **10** of the electrometer portion **2*a*** is grounded and the screen grid **12** and anode **14** thereof, are connected through respective dropping resistors **16** and **18** to a line **20** maintained at a regulated voltage of 8 volts. Resistor **18**, as indicated in Fig. 1, is made adjustable to serve as the hold control. The screen grid **12** is also connected through an adjustable resistor **22**, comprising the dim control, to a front contact associated with the grounded armature **24** of the sensitive relay **26** in the anode circuit of tube **4**.

Anode **14** of section **2*a*** is connected through a resistor **28** to the control grid **30** of section **2*b***. The cathode of section 2*b* is operated at above ground potential by virtue of a connection to the junction of a pair of resistors **32** and **34** connected in series between the 8 volt line **20** and ground. The 8 volt line **20** is connected directly to the screen grid of section 2*b* and, through a dropping resistor **36** to the anode **38** of that section.

Anode **38** of section 2*b* is also connected through a capacitor **40** to the second or control grid **42** of the output tube **4**. The control grid **30** of section 2*b* is connected through a capacitor **44** to the junction between a resistor **46** and capacitor **48** series connected between the anode **50** of tube **4** and ground. The circuit comprising resistor **46** and capacitor **48** serves as a potential divider and phase shifter for pulses fed back from anode **50** to grid **30**.

The cathode of tube **4** is grounded and the first or space charge grid thereof is connected directly to the 8 volt line **20**. A grid bias resistor **52** of relatively large magnitude, say two megohms, is connected between the grid **42** and ground. A car carried battery (not shown) of the order of 12 or 13 volts is connected to the anode **50** through the relay **26** and is connected through the winding of a power relay **54** to the back contact associated with armature **24** of relay **26**.

Any suitable means, as for example, a gas filled regulator tube of conventional construction may be employed for obtaining from the battery the regulated 8 volts for application to line **20**. Such means have not been shown because forming no part of the present invention and because adequately disclosed in the pending applications to which reference has already been made.

The operation of the circuit of Fig. 1 will now be given with reference to that figure and also with reference to the graph of Fig. 2. Under conditions of low or no light on the photocathode of the photoelectric tube **8** electrons from the heated cathode of the electrometer portion of tube **2** will accumulate on the grid **6** and drive that grid sufficiently negative to maintain relatively low current through the electrometer portion 2*a* of the tube. When dropping resistor **18** is of say 100 K and resistor **28** of about 300 K then the potential at the anode **14** will be relatively high say 2 volts or higher and the potential of grid **30** will be at least about one and one-half volts above ground, or zero with respect to the cathode. Accordingly section 2*b* of tube **2** will be in its most conductive condition. The value of resistor **28** is so chosen that the potential of grid **30** under such conditions of low current through the electrometer portion 2*a* will be high enough to insure that the current through the second half of tube **2** is that corresponding to saturation at the operating voltages. In Fig. 2 wherein plate potential above ground is plotted against grid potential above cathode potential a grid voltage of zero volts corresponds to the operating point at which saturation occurs. Increase in positive potential of the grid beyond this value can not change the anode potential because the anode is already taking all the current it can draw. Decrease in grid potential below this operating point will however, reduce the current through the section 2*b* and thereby result in increase in anode potential.

Still assuming the no or low light conditions, the tube **4** will be conducting and will pass a steady current of the order of 15 milliamperes. Accordingly relay **26** is energized holding open the circuit of the power relay **54** at the back contact of armature **24** and holding closed the circuit through the dim control **22** to the screen grid **12** of the electrometer portion 2*a* of tube **2**. No oscillation of the circuit including the second half of tube **2** and the relay control tube **4** will occur under these conditions of low or no light.

If now light of predetermined intensity, determined in part by the adjustment of resistor **22** in the circuit of the screen grid, falls on the photocathode of tube **8** the negative charge accumulated by control grid **6** will dissipate through the photoelectric tube thereby raising the potential of grid **6** and causing increased current to flow through the electrometer portion 2*a*. The potential at anode **14** therefore decreases and that at grid **30** likewise decreases. When the potential at grid **30** is sufficiently below the operating point (zero with respect to the cathode), the current through section 2*b* will decrease raising the potential at anode **38** and applying a positive pulse through condenser **40** to control grid **42** of tube **4**. This will result in a momentary increase in current through tube **4** which increase is reflected as a drop in potential at anode **50** and, through the phase shifting and potential dividing circuit comprising resistor **46** and capacitor **48**, as a negative pulse applied to grid **30**. This negative pulse on grid **30** causes a positive pulse to appear at anode **38** and at control grid **42** which in turn reinforces the negative pulse at anode **50**. When tube section 2*b* reaches cut off, the potential at anode **38** can rise no further. Consequently when the pulse applied through condenser **44** dissipates, the anode potential falls and the reverse cycle is initiated. Thus the oscillatory circuit comprising the section 2*b* and the relay control tube **4** will break into oscillation and continue to oscillate so long as the current through the electrometer portion 2*a* is sufficient to maintain the grid **30** at an average potential below that of the operating point indicated in Fig. 2.

Because of the presence of the inductive winding of the sensitive relay in the anode circuit of tube **4** the pulses created at anode **50** will be strongly negatively peaked and of a magnitude more than sufficient to maintain the circuit in oscillation. The steady current through tube **4** which is effective to hold the relay energized will gradually decrease during oscillation of the system due partly to the decrease in the average potential of grid **42** resulting from the self-rectifying properties of the grid circuit including the high resistor **52** and capacitor **40** and to the fact that the inductive kick drives the anode potential so low during positive excursions of the grid voltage that average plate current is reduced.

The potential dividing circuit comprising resistor **46** and capacitor **48** serves to reduce the magnitude of the pulses applied from anode **50** through capacitor **44** to control grid **30** and at the same time to shift the phase of these pulses to insure that oscillation will be continued so long as a light signal is present.

When the relay **26** releases the circuit of the power relay **54** is closed through armature **24** and the dimming switch (not shown) will be actuated. The circuit through adjustable resistor **22** is opened at the front contact of armature **24** and consequently the potential of the screen grid **12** of the electrometer portion of tube **2** is increased to increase the sensitivity of the circuit and to thereby insure that dimming of the lights of an approaching car will not cause return of the circuit to high beam conditions.

The control grid **6** of the electrometer portion 2*a* is preferably taken out through a top cap as indicated diagrammatically in Fig. 1 by the bracket **56**. Preferably also this portion of the double tube **2** is of the construction illustrated and described in my said copending application Serial No. 547,508 filed November 17, 1955, which construction insures that change in cathode emission will not appreciably affect anode current. The construction involves a grid pitch-grid cathode spacing ratio less than unity to avoid "island formation" as explained more fully in said copending application.

Also the internal lead from grid **6** to the top cap is preferably so disposed with respect to the anode **38** of section 2*b* that there will be a capacitative coupling between that anode and grid **6** and the parts conductively connected thereto such as the top cap **56**. Such coupling, of the order of 0.1 micromicrofarad, which is symbolized in Fig. 1 by the condenser **58** shown in dotted lines, serves to increase the speed of response of the circuit to change in light intensity, as explained in the said copending application. When the negative charge on grid

6 starts to dissipate as a result of increase in intensity of light, and current through section 2*b* consequently reduces, the increase in potential at anode **38**, through its capacitative coupling to grid **6**, causes the potential of that grid to rise more quickly and hence accelerates the response of the circuit.

In the construction of double tetrode described in the said copending application the heaters are provided with unequal thickness of insulation to insure that the first half of the tube will heat up more promptly and thereby insure that when the circuit is first put into operation the dimming switch will be operated irrespective of light intensity. In the present circuit this result is automatically obtained during the charging of grid **6** from the cathode. Hence unequal rate of heating of the sections of the double tube is unnecessary and undesired. Both heaters are therefore preferably fast acting.

In the circuit of Fig. 1 the control grid **30** of tube section **2*b*** is connected both to anode **14** to receive control potential therefrom and through capacitor **44** to the potential dividing and phase shifting network to receive pulses therefrom during a light signal. An alternative arrangement, wherein the feedback pulses are applied to the screen grid, rather than to the control grid of tube section **2*b*** is illustrated in Fig. 3.

In Fig. 3, control grid **30** of section **2*b*** is shown connected only to anode **14** of the electrometer section **2*a*** and the screen grid **60** is shown connected to capacitor **44**. The resistor between anode **14** and grid **30** is omitted and a potential dropping resistor **62** is included in the connection between the 8 volt line **20** and grid **60**. The remainder of the circuit, being identical with that of Fig. 1, is not shown in Fig. 3. The operation of the circuit of Fig. 3 does not differ in any material respect from that described with reference to Fig. 1. The feedback connection to the screen grid rather than to the control grid has the effect, however, of keeping oscillatory current out of the dropping resistor in the anode circuit of the electrometer portion of tube **2**.

An illustrative set of specific values of the several electrical components of the new system are given in the following table. Electrical components having values different from those given in the table could be employed in a system operating in accordance with the invention, as will be obvious to those skilled in the art.

Table of illustrative values of circuit components

R16	680 ohms.
R18	100 kilohms—variable.
R22	10 kilohms.
R28	300 kilohms.
R32	5 kilohms.
R34	1 kilohm.
R36	100 kilohms.
R46	22 kilohms.
R52	2.2 megohms.
C40	.002 microfarad.
C44	.001 microfarad.
C48	.0005 microfarad.
Capacitative coupling 58 about	.01 micromicrofarad.

The invention has now been described with specific reference to control of the dimming switch of automobile headlights in response to incident light. Obviously the utility of the new oscillatory circuit of the invention is not limited to such specific application.

The following is claimed:

1. An oscillatory circuit comprising a first and second electronic tube section each having an anode and a cathode and at least one grid, means capacitatively coupling the anode of each section with a grid of the other section, a first conductive impedance, means for impressing a potential difference across said impedance and said first section in series, grid biasing means for said first section, a second conductive impedance, means for impressing a potential difference across said second impedance and second tube section in series, said second impedance being of a magnitude selected with reference to the magnitude of the potential difference impressed across said second impedance and said second tube section and with reference to the characteristics of such tube section as to cause such section to be current saturated when the potential of a grid thereof with respect to the cathode thereof is at or above a predetermined value, and means for initiating oscillation of the circuit by depressing the potential of said last mentioned grid below said predetermined value and for quenching oscillation of said circuit by raising the potential of said last mentioned grid above said predetermined value, said last mentioned means comprising a separate energized circuit connected to said last mentioned grid and to the cathode of said second section and having means therein for varying the potential of said last mentioned grid.

2. The oscillatory circuit according to claim 1 wherein said first conductive impedance is an inductive impedance whereby during oscillation of said circuit the average current through said first tube section decreases.

3. The oscillatory circuit according to claim 2 including a resistor and capacitor connected in series across said first tube section to serve as a potential dividing and phase shifting network for pulses fed back to a grid of said second tube section, said means capacitatively coupling said last mentioned grid of said second tube section to the anode of said first tube section comprising a capacitor connected between said grid and the junction of the resistor and capacitor of said network.

4. The oscillatory circuit according to claim 3 wherein said inductive impedance comprises the winding of a sensitive relay energized by the steady current through said first tube section when the circuit is not oscillating and wherein said grid biasing means comprises a high bias resistor connected between the cathode and the grid of said first tube section that receives pulses from said second tube section when the circuit is oscillating, whereby during oscillation of the circuit the average current through said first tube section and relay winding decreases to release the relay because the grid is driven negative by virtue of the self-rectifying properties of the cathode grid circuit including said bias resistor and because the inductive kicks at the anode depress the anode potential during parts of the time that positive pulses are impressed upon the grid.

5. The oscillatory circuit according to claim 1 wherein said second conductive impedance comprises two resistors one connected to the anode of said second tube section and the other connected to the cathode of said second tube section and wherein said separate energized circuit comprises a third electronic tube section, a dropping resistor, means for impressing a potential difference across said dropping resistor and third electronic tube section in series, and a connection between a grid of said second tube section and the junction of said third tube section with said dropping resistor whereby the potential applied to the grid of said second tube section varies with the current through said third tube section.

6. The oscillatory circuit according to claim 5 including a resistor in said connection to reduce grid current of said second tube section and to minimize oscillatory current in the dropping resistor connected to the third tube section.

7. The oscillatory circuit according to claim 1 wherein said second tube section has both a control grid and a screen grid, said control grid being connected to said separate energized circuit and coupled to the first tube section for reception of voltage pulses therefrom when the circuit is oscillating, said screen grid being connected for operation at constant positive potential.

8. The oscillatory circuit according to claim 7 wherein said separate energized circuit comprises a third electronic tube section and dropping resistor, means for impressing a potential difference across said third electronic tube

section and dropping resistor in series and a resistor connected between the control grid of said second tube section and the junction of said third tube section with its dropping resistor.

9. The oscillatory circuit according to claim 1 wherein said second tube section has both a control grid and a screen grid, said control grid being connected to said separate energized circuit and said screen grid being connected through a dropping resistor to said means for impressing a potential difference across said second impedance and second tube section in series and being coupled to said first tube section for reception of voltage pulses therefrom when the circuit is oscillating.

10. The oscillatory circuit according to claim 1 wherein said second impedance comprises a dropping resistor connected to the anode of said second tube section and a cathode resistor connected to the cathode of said second tube section and wherein said separate energized circuit includes a third electronic tube section having a cathode, at least one grid and an anode, a third conductive impedance, means for impressing a potential difference across said third impedance and said third tube section in series and a connection between the anode of said third tube section and the grid of said second tube section, said second and third tube sections having a common envelope provided with a top cap to which the grid of said third tube section is internally connected, the electrodes within said common envelope being so oriented and the internal connection to the top cap being so disposed that there will be an inherent small capacitative coupling between the anode of said second tube section and the grid of the third tube section which accelerates response of the circuit to change in potential of the grid of the third tube section.

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