Nov. 8, 1932. E. O. HULBURT ET AL 1,886,813

LIGHT CONTROL CIRCUIT

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Fig. 1

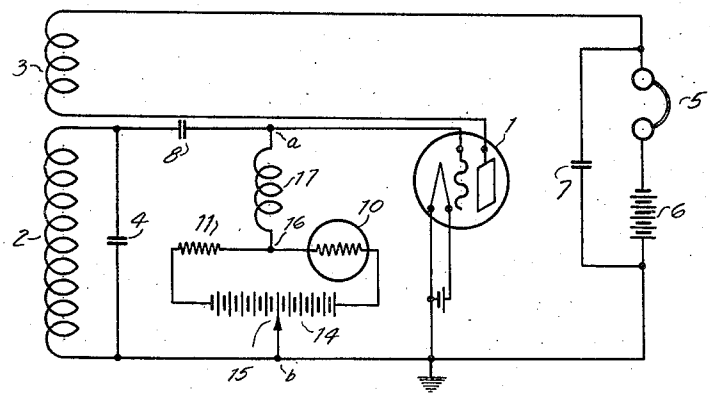
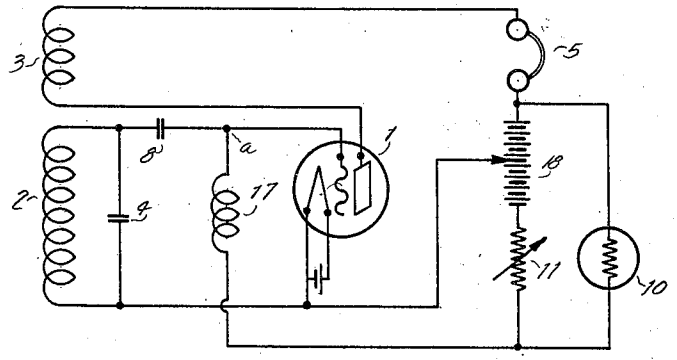


Fig. 2



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FIG. 3

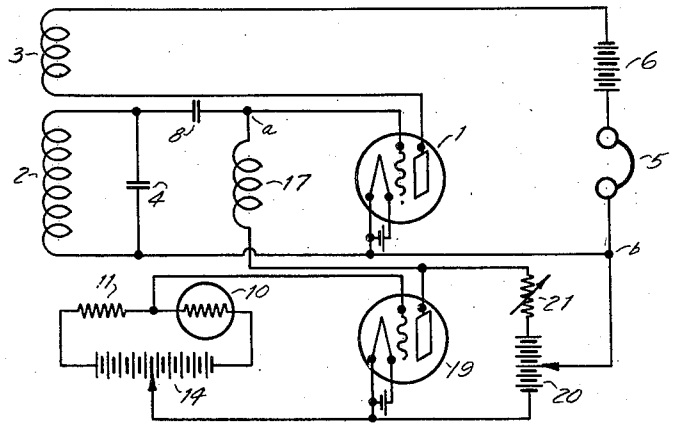


FIG. 4

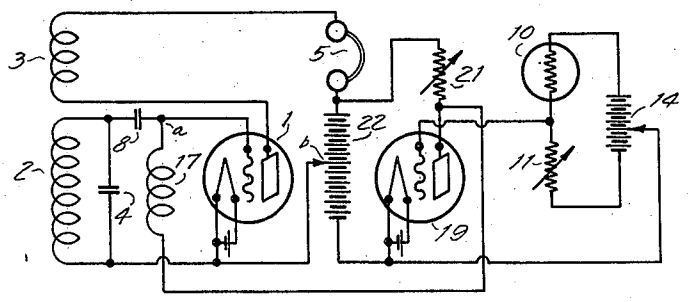
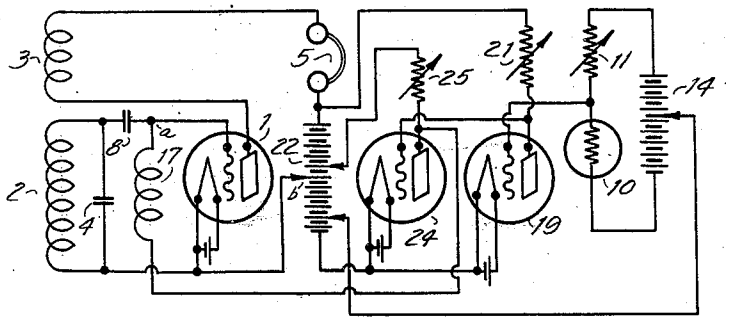


FIG. 5



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FIG. 6

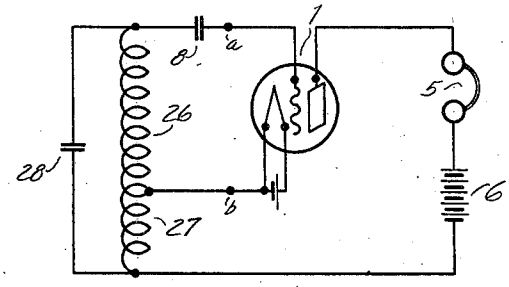


FIG. 7

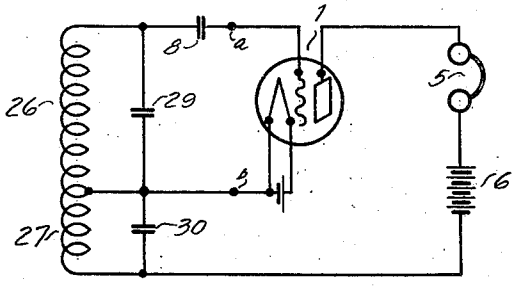
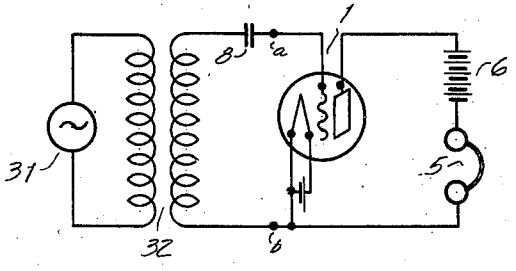


FIG. 8



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Fig. 9

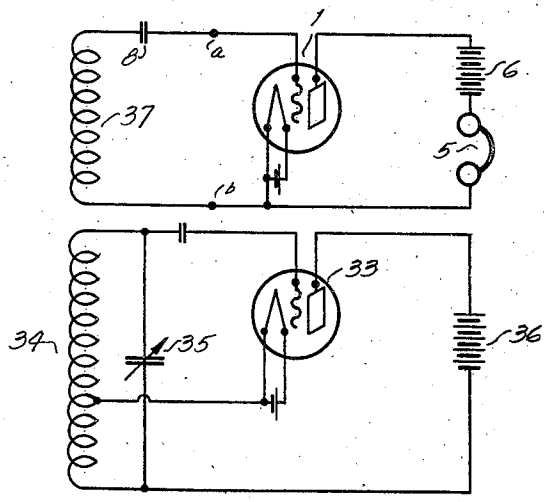
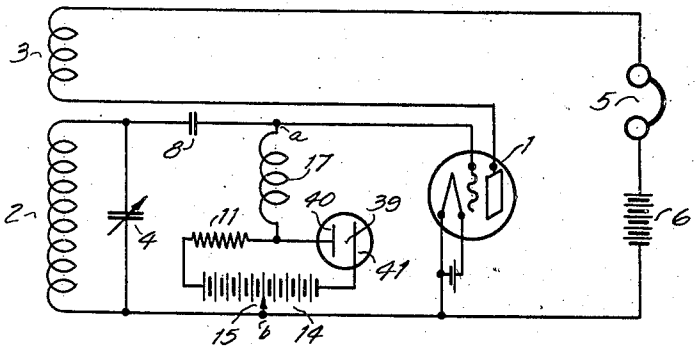


Fig. 10



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Fig. 11

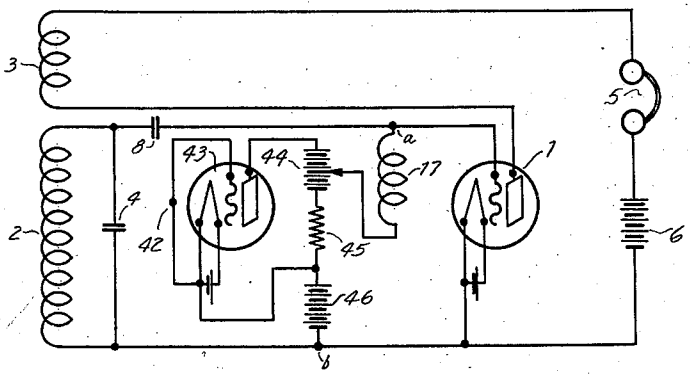
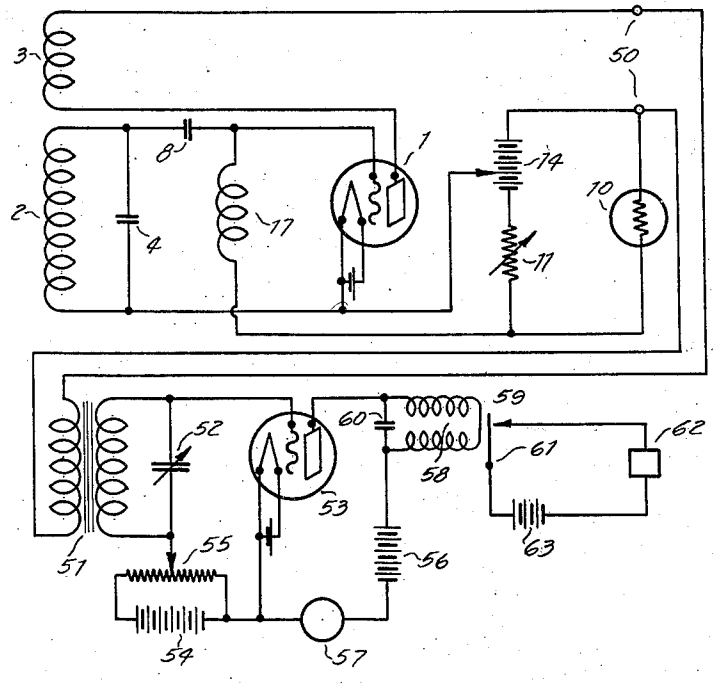


Fig. 12



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UNITED STATES PATENT OFFICE

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LIGHT CONTROL CIRCUIT

Application filed December 23, 1927. Serial No. 242,266.

Our invention relates broadly to electrical control systems and more particularly to circuit arrangements for controlling the condition of an electrical circuit in accordance with variations in the intensity of a source of light.

One of the objects of our invention is to provide a circuit arrangement of relatively high sensitivity to changes in light intensity for controlling an indicating element in accordance with the changes in light intensity.

Another object of our invention is to provide an electron tube circuit arrangement with connections to a light sensitive element for controlling a responsive device in accordance with fluctuations in light intensity.

Other and further objects of our invention will be understood from the specification hereinafter following by reference to the accompanying drawings in which:

Figure 1 shows a circuit arrangement employing the principles of our invention; Fig. 2 shows a simplified circuit arrangement for performing the functions of the circuit shown in Fig. 1; Fig. 3 shows a modified form of light control and circuit arrangement for actuating a responsive device; Fig. 4 shows a simplified circuit arrangement for carrying out the principles of operation of the circuit in Fig. 3; Fig. 5 is an extended circuit arrangement embodying the principles of the circuit shown in Fig. 4; Figs. 6 and 7 show electron tube oscillator circuits connected with light control circuits in accordance with our invention; Fig. 8 shows a light control circuit in which an external source of oscillations is impressed upon the light control circuit; Fig. 9 illustrates an arrangement of electron tube oscillator arranged externally with respect to the light control circuit; Fig. 10 shows the arrangement of a photo-electric cell in the light control circuit of our invention; Fig. 11 shows the arrangement of an ionization chamber in the control circuit in place of the photo-electric cell shown in Fig. 10; and Fig. 12 illustrates a circuit arrangement for carrying out one application of our invention where a relay system is actuated in accordance with changes in light intensity.

In general use in commerce and in the laboratory there are a number of light sensitive devices, some of which because of their mechanical form are properly termed light sensitive "cells"; others are more properly termed "chambers"; still others, such as thermocouples, perhaps fall under neither of these categories, although a vacuum thermocouple could certainly be called a "light sensitive cell". The light sensitive devices which are employed in the circuit arrangements of our invention are:

(*a*) Resistance cells, such as those of selenium, copper oxide, thalium sulphide, and many others. These types are usually sensitive in infra-red and visible light and relatively insensitive to ultra-violet light.

(*b*) Photoelectric cells, such as those of metals, particularly the alkali metals, the alkali metal hydrides, etc. These types are usually sensitive in the visible and ultra-violet regions of the spectrum, and less so in the infra-red.

(*c*) Ionization chambers, are usually sensitive to X-rays and are used in the spectrophotometry of X-rays.

(*d*) Thermocouples or the thermopiles, are sensitive throughout the spectrum, but usually are more used for the longer waves than for the shorter ones.

Our invention in its simplest form consists of a relaxation circuit, one of a general class of circuits known to the radio art as "howling" circuits. At a sensitive point of the relaxation circuit is attached a light sensitive cell by means of a potentiometer circuit.

In carrying out our invention we employ an oscillating circuit shown in Fig. 1. The three electrode vacuum tube 1, together with coils 2 and 3, condenser 4, telephones 5 and plate battery 6 form the oscillatory circuit. The by-pass condenser 7 may or may not be used as required. If the grid blocking condenser 8 by-passed by a resistance r (connecter between points a and b) is introduced, the circuit becomes a relaxation circuit, a form of "howling" circuit, which when suitably adjusted produces an audible note, more or less musical, in the telephones 5. If the resistance r is changed the quality of the audible note is changed, usually its pitch. So that if r is a

light sensitive cell, as for example a selenium, or a copper oxide, etc., cell, whose resistance changes when it is exposed to light, the circuit becomes an indicator or detector of light pulses.

The circuit in Fig. 1 with r constituted by a light sensitive cell, has a certain degree of sensitivity to light pulses or signals. In order to increase the sensitivity we have introduced the light sensitive cell 10 by means of a potentiometer circuit made of a resistance 11, the cell 10 and a battery 14. An interior point 15 of the battery 14 is connected to the filament and ground (the metal case of the enclosing box). The point 16 between 11 and 10 is connected to the grid at a through the choke 17. The choke is used if necessary. It usually improves the operation if the 2–4–3 circuit oscillates at radio frequency, and in this case the choke is a radio frequency choke. The circuit in Fig. 1 is highly sensitive and its adjustment is relatively simple, permanent and not too critical. The circuit operates well when the circuit 2–4–3 is varied over a wide range of frequencies, from 10^7 cycles per second (i. e. 30 meters wave length) to a frequency in the audible range. Various types of electron tubes have been used satisfactorily in the circuit. 8 is a small grid condenser about 50 mmf. Resistance 11 has a value of 1 to 10 megohms, its exact value depending on the particular cell 10. 11 may be variable, for purposes of adjustment, either continuously or in steps. Thalofide cells and commercial selenium cells have been used at 10 with success. Batteries 14 and 6 are each about 50 volts to 100 volts, except in the case of a power tube ($7\frac{1}{2}$ watts) when a higher voltage is required. The circuit is adjusted to its most sensitive condition by varying 11 and the battery tap 15.

It is seen that the circuit of Fig. 1 contains two batteries 6 and 14. These may be combined into one to give the simpler circuit shown in Fig. 2 at 18. A portable set was made up using the circuit of Fig. 2 and used in field tests. Using a thalofide cell in the set, signals were received at night from a 2000 watt tungsten lamp (moving picture projection lamp of a commercial type), screened with a black glass which transmitted only infra-red radiation of a wave length greater than 0.9μ at distances up to one-quarter or one-half mile (a conservative estimate), with no focusing mirrors or lenses either on the transmitting lamp or on the receiving cell. The distance at which signals may be received may be increased by the use of focusing devices.

Instead of impressing the potentiometer circuit directly on to the relaxation circuit by attachment at points a and b, Fig. 1, we have improved the sensitivity by amplifying the potentiometer circuit by means of another standard tube, either a receiving or a power tube, introduced into the circuit in the proper way. The circuit is shown in Fig. 3, in which 1—2—3—4—5—6 is the same relaxation circuit as before. The same potentiometer circuit 11—10—14 of Fig. 2 appears in Fig. 3 and is connected to the points a and b of the relaxation circuit through the amplifying tube circuit 19—20—21. It is noticed that there are now three separate high potential (50 to 100 volts) batteries in the circuit. By making suitable connections these three batteries may be reduced to two. One method by which this is accomplished is shown in Fig. 4 where battery 22 takes the place of batteries 6 and 20.

The amplification in the potentiometer circuit may be extended further by introducing another stage of amplification. A circuit in which this is done is shown in Fig. 5, wherein reference character 24 represents an electron tube constituting an amplifier stage interposed between the tubes 1 and 19. A control resistor 25 is arranged in the output circuit of tube 24 and connects to a suitable potential point on battery 22.

We have shown in Figs. 6 and 7 modified forms of oscillator circuits which may be employed with the potentiometer control circuit of our invention. In Fig. 7 the oscillator includes electron tube 1 having its input circuit completed through inductance 26 and its output circuit completed through inductance 27 with source of potential 6 and telephones 5 therein. A condenser 28 is provided for facilitating the establishment of oscillations, and the potentiometer circuit is connected across points a and b which has been described in connection with the previous figures.

In Fig. 7 we have illustrated both sections 26 and 27 of the inductance which is disclosed in the input and output circuits as shunted by condensers 29 and 30. The potentiometer circuit is connected with the same points a and b.

In Figs. 8 and 9 we have shown a modified control circuit in which audio frequency oscillations are produced by means of generator 31, which feeds the circuit of electron tube 1 through transformer 32. The potentiometer circuit may be connected with points a and b as disclosed in connection with the previous figures. Instead of employing a machine type generator we may utilize an oscillating tube circuit in the form of an electron tube system, as represented by reference character 33 in Fig. 9, where the input and output circuits are coupled through inductance system 34 tuned by means of condenser 35. The plate circuit may be provided with a high potential source 36. The inductance system 34 is coupled with inductance 37 in the input circuit of the amplifier tube 1, provision being made for the connection of the light control circuit across points a and b.

Audio frequency amplification may be applied to the several circuits heretofore illustrated in any suitable manner for increasing the amplitude of the control current.

We have utilized other control devices beside light sensitive resistance cells, and Figs. 10 and 11 show the circuit arrangement of our invention employed with a photoelectric cell and a thermocouple.

In Fig. 10 the potentiometer circuit is shown as including the photoelectric cell 39 including the sensitive surface electrode 40 which is connected to the negative terminal of battery 14 and the collector terminal 41 which is connected to the positive terminal of battery 14. We have used both the alkali hydride photoelectric cell and also the thalofide cell. When using the alkali hydride cell the apparatus is sensitive to visible and ultra-violet light, while with the use of the thalofide cell the apparatus is sensitive to the visible and infra-red light. In order to obtain the highest degree of sensitivity with the alkali hydride cell the voltage at 14 should be approximately 150 volts. We have used other commercial photoelectric cells and also sodium cells in glass and with quartz windows. With the latter type of cell the set is sensitive to the shorter ultra-violet waves which are transmitted by the quartz but absorbed by the glass. An ionization chamber may be substituted in place of the photoelectric cell 39 in Fig. 10, and with this change the set functions more sensitively to X rays and can be used as a detector and measurer of X rays.

In Fig. 11 we have shown the control circuit arrangement with a thermocouple or thermopile 42 used as the control means. It is not practicable to place the thermocouple directly in the place of the circuit of Fig. 10 because the resistance with usual thermocouples is too low. We have found it necessary to place the thermocouple 42 in the grid circuit of an amplifier 43, the plate circuit of which includes the battery 44 and resistance 45. The output circuit is connected across points *a* and *b* of the control circuit of tube 1. Inductance 17 is connected in one side of the circuit and source of potential 46 in the other side thereof. The circuit has been found to be highly sensitive to long infra-red waves as well as to the shorter ones.

In the circuits heretofore explained the response to the light impulses is observed by telephone receivers 5 as an audible note. The control circuit may be used to operate a relay for controlling a circuit maker or breaker as represented in Fig. 12.

The output of the control circuit is represented at terminals 50 leading to the input of the audio frequency transformer system 51. The transformer system 51 has its secondary tuned by means of condenser 52 for adjusting the input of the electron tube amplifier 53 to a desired frequency. The potential upon the grid of the electron tube 53 is controlled from battery 54 and shunt resistance 55. The output circuit of the amplifier tube 53 includes high potential source 56, ammeter 57 and the windings 58 of relay 59. A condenser 60 is connected in shunt with the windings 58. Contacts 61 are controlled by the relay windings 58 for opening and closing a circuit to any desired form of load represented generally at 62, which may be in series with potential source 63. The relay is controlled by reason of the effects of variable light upon the light sensitive device 10. Any form of responsive device may be included in the circuit, such as a bell, an indicator, an alarm or other movable device which may change its condition in accordance with the change in effect of light rays upon the light sensitive cell.

We have found the circuit arrangements described herein highly efficient in operation, and while we have described certain preferred embodiments of our invention, we desire that it be understood that no limitations upon our invention are intended other than are imposed by the scope of the appended claim.

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

A light controlled circuit comprising an electron tube having grid, filament and plate electrodes, an input circuit interconnecting said grid and filament electrodes, an output circuit interconnecting said plate and filament electrodes, means interlinking said circuits, a light sensitive element, a resistance and a high potential source of energy constituting a looped branch of said input circuit and a choke coil connected to said looped branch and forming, together with the latter, a series-connection between the grid and filament electrodes of said input circuit, the respective elements of said light controlled circuit being so disposed in relation to one another that high frequency currents are excluded from said looped branch and variations in the intensity of light impinging upon said light-sensitive element are caused to control the grid bias of said electron tube.

In testimony whereof we affix our signatures.

EDWARD O. HULBURT.
WILLIAM H. CREW.