Sept. 15, 1942. W. J. ALBERSHEIM 2,295,536

LIGHT SENSITIVE CIRCUIT

Filed Oct. 8, 1941 2 Sheets-Sheet 1

FIG. 1

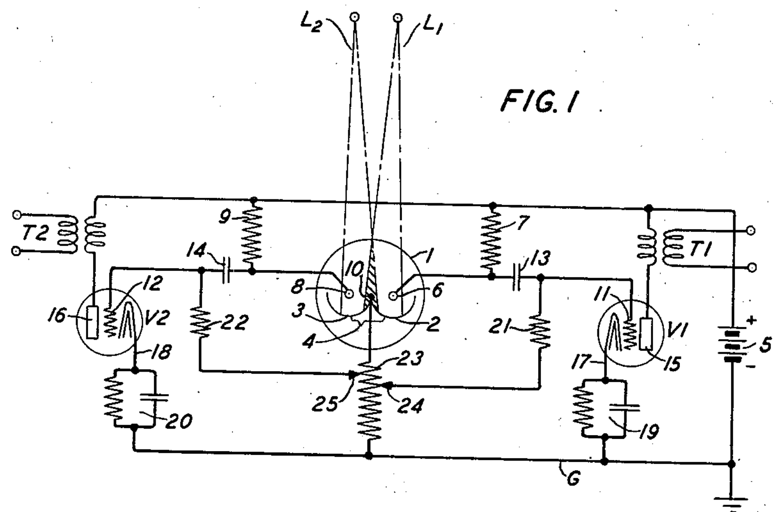
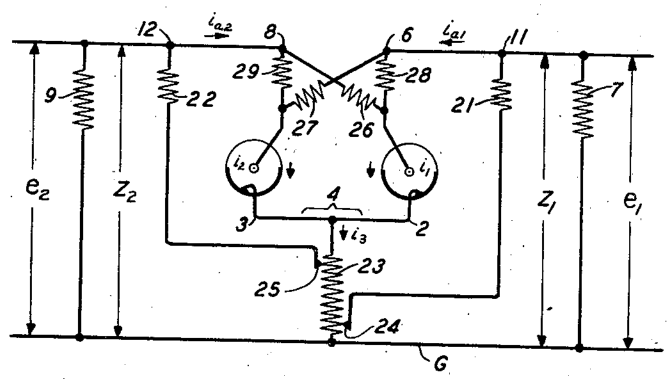


FIG. 2



INVENTOR
W. J. ALBERSHEIM
BY
G. H. Heydt.
ATTORNEY

Sept. 15, 1942. W. J. ALBERSHEIM 2,295,536
LIGHT SENSITIVE CIRCUIT
Filed Oct. 8, 1941 2 Sheets-Sheet 2

FIG. 3

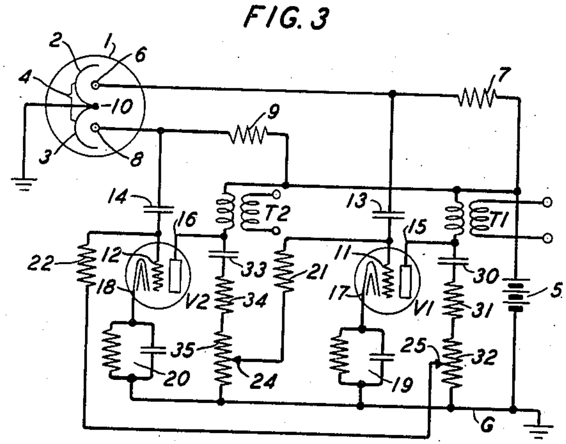
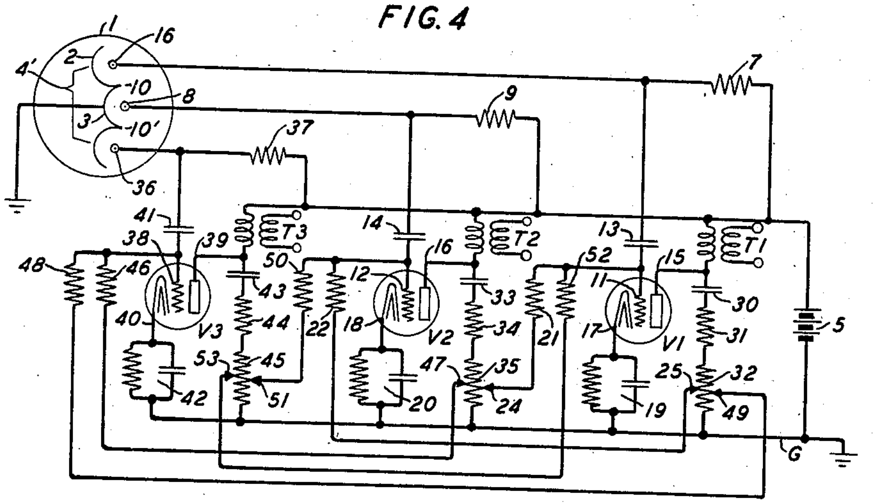


FIG. 4



INVENTOR
W. J. ALBERSHEIM
BY
G. H. Heydt
ATTORNEY

Patented Sept. 15, 1942

UNITED STATES PATENT OFFICE

2,295,536

LIGHT SENSITIVE CIRCUIT

Walter J. Albersheim, Great Neck, N. Y., assignor to Western Electric Company, Incorporated, a corporation of New York

Application October 8, 1941, Serial No. 414,083

16 Claims. (Cl. 250—41.5)

This invention relates to improvements in light-sensitive circuits, particularly those employing photosensitive devices, such as photoelectric cells, having plural electrodes of one polarity and a common electrode of opposite polarity. An example of such a photocell is that described in my U. S. Patent 2,198,650, April 30, 1940; a commercial embodiment of that invention is the Western Electric 9A cell, in which are two anodes and a common cathode in the same glass envelope.

In a photocell of this type it is desired that no light intended for one portion only of the cathode shall reach the remaining cathode portion and further that no electrons or other charged particles belonging to the current conduction from one anode to its corresponding cathode portion shall stray over to take part in the current conduction from the other anode to the other portion of the cathode. In practice it is found that neither of the foregoing requirements is fully met. In the Western Electric 9A cell, for example, optical and electronic crosstalk is greatly reduced by the cell construction shown in U. S. Patent 2,198,650 above referred to, but enough crosstalk remains to bring it about that if the two currents corresponding to the separate anode-cathode paths are equal, a small fraction, say 5 per cent, of each such current is due to crosstalk from the other conducting path. Optical crosstalk arises from direct incidence of light on the cathode portion for which it is not intended and also from scattered reflections of light within the cell. Electronic crosstalk arises in part from electrons which escape their appropriate anode to reach the other anode, in part from scattering of conducting particles released from the glass envelope by electronic bombardment, but chiefly from secondary electrons due to collisions between photoelectrons and gas molecules.

There are various purposes for which such photocells with plural anodes and common cathode may be used in the reproduction of sound films. The cells in practical use are provided with two anodes and a common cathode and are customarily called push-pull cells because they have been principally used for the reproduction of two sound records side by side on the same film, both being records of the same sound source, but everywhere differing in phase by 180 degrees. In such a case the existence of crosstalk of the low value characteristic of the 9A cell results in no perceptible damage to the reproduced sound, the effect being only a reduction in volume of a few tenths of a decibel. Again where the two film tracks are sound records corresponding to the same sound source but with different microphone positions such as stereophonic records, the only effect of crosstalk will be a slight loss in effective localization, whereas the quality is not impaired because, as in the push-pull case, the two records are of the same acoustic character.

However, it has been proposed to use such a photocell for the reproduction of two parallel film tracks of which one is a sound track and the other is a record related to the sound record but distinct therefrom, such as a volume control track for regulation of the gain of the reproducing amplifier. In this case, since the control track is usually a record of a high frequency modulated by the envelope of the sound signal, crosstalk from it into the sound record part of the cell introduces noises fatal to good sound reproduction. Crosstalk from the sound record into the control track reproduction has the effect of confusing the gain controls.

The object of this invention is the substantially complete compensation of undesired currents such as the crosstalk above described in the separate outputs of photoelectric cells having two or more anodes and a cathode common thereto, for the types of sound film reproduction above enumerated or for any other application in which it may be proposed to use such photocells. This object is attained by providing a method and circuits adapted to eliminate the undesired voltage components from the grids of amplifying tubes appropriately connected each to one of the photocell outputs while leaving the desired voltage components effective on said grids at nearly the same values as if crosstalk were wholly absent.

The method and circuits of the invention will be fully understood from a detailed description of the accompanying drawings in which:

Fig. 1 shows a preferred embodiment of this invention applied to a photocell with dual anodes and common cathode;

Fig. 2 is a symbolic equivalent of Fig. 1 showing the current and voltage relations therein;

Fig. 3 is a circuit alternative to that of Fig. 1; and

Fig. 4 is an extension of the circuit of Fig. 3, enabling this invention to be applied to a photocell having three anodes and a common cathode.

In all figures corresponding parts are identified by the same reference numerals.

Referring to Fig. 1 two light beams L_1 and L_2, which may be transmitted from a single light source through two separate film tracks, are incident on the photosensitive surface of cathode 4 of photocell 1 which cell is provided with two anodes to which cathode 4 is common. These light beams are intended each to illuminate one portion only of surface 4, as L_1 for portion 2, and L_2 for portion 3. As indicated in Fig. 1, however, some of L_1 reaches portion 3 and some of L_2 reaches portion 4. A voltage of, say 90 volts from battery 5 is applied through polarizing resistor 7 to the photocell anode 6 facing cathode portion 2, and through polarizing resistor 9 to anode 8 facing cathode portion 3. Under the influence of the incident beams L_1 and L_2, photoelectric currents flow in the two portions of the cell incompletely separated by cusp 10 of cathode 4 and as previously explained, each of these currents contains a small component properly belonging to the other.

The grids 11 and 12 of amplifying tubes V1 and V2 respectively are connected to cell anodes 6 and 8, grid 11 to anode 6 through capacitor 13, grid 12 to anode 8 through capacitor 14. Voltage to plates 15 and 16 of the amplifying tubes may be supplied as in Fig. 1 from the positive terminal of battery 5 through the primaries of transformers T1 and T2, respectively, or may be supplied from a separate voltage source. Cathodes 17 and 18 of tubes V1 and V2, respectively, are connected to ground and the negative terminal of battery 5 (or other voltage supply) through the conventional biasing resistors and by-pass condensers as indicated by 19 and 20 in Fig. 1. The filament heating circuits are not shown. The tube outputs are taken from the secondary terminals of transformers T1 and T2. In the conventional circuit mesh connecting grid and cathode of an amplifying tube to the output terminals of the photocell, the photocell cathode is connected to ground, to the negative battery terminal and to the end of the tube grid leak remote from the grid. According to this invention, however, a potentiometer 23 is inserted between cathode 4 and the ground line G. Grid leaks 21 and 22 are connected as shown in Fig. 1 to separately adjustable taps 24 and 25, respectively, on potentiometer 23 instead of directly to ground line G. The insertion of potentiometer 23 between cathode 4 and ground line G and the separate connection of grid leaks 21 and 22 to adjustable taps on potentiometer 23 constitute the circuit improvement of this invention as applied in solving the problem of amplifying separately and without mutual contamination modulated photocell currents corresponding to modulations of light flux in the incident beams L_1 and L_2. Beams L_1 and L_2 may be modulated, for example, by a sound record and by a volume control record, respectively, on a photographic film. Such a film and the mechanism for feeding it past an exciting light source, together with the optical system for illuminating the film and effecting the separation of beams L_1 and L_2 are not shown, inasmuch as they form no part of this invention.

How the method of the invention attains the desired object will be apparent from the following discussion with references therein to Fig. 2. If, for example, photocell 1 is a Western Electric 9A cell and if light beams L_1 and L_2 are of equal intensity, each anode-cathode path in the cell carries a current of 1.00 in arbitrary units of which 0.95 is its proper current and 0.05 is the undesired current contributed by crosstalk from the other anode-cathode path. At the same time, these paths contribute equally to the current in the potentiometer inserted between the cell cathode and ground. In each anode-cathode path the ratio of desired to undesired current is 95 to 5, but the currents to be separated appear in the cathode-to-ground potentiometer 24, each equal to the total current in either cell path.

The same distributions are characteristic of the alternating currents provoked in the photocell by modulation of the light beams L_1 and L_2 provided these beams are both modulated to the same extent. Therefore if amplifying tubes, which are suitably Western Electric 262B tubes, are connected one each to one of the photocell paths in the conventional manner the grid voltage of each tube will contain desired and undesired components also in the ratio 95 to 5. The current in the return conductor from cathode 4 to ground line G will consist of two approximately equal currents each corresponding to modulation of one of the light beams L_1 and L_2. The voltage drop across potentiometer 23 inserted according to this invention, therefore also consists of two approximately equal components. It will be understood that potentiometer 23 may comprise two parallel resistors provided one with tap 24, the other with tap 25.

Fig. 2, a circuit symbolically equivalent to that of Fig. 1, exhibits instantaneous relationships of the alternating currents therein. For simplicity, battery 5, capacitors 13 and 14 are replaced by short-circuit connections since Fig. 2 concerns only alternating currents. It is an object of this invention to impress upon grid 11 a voltage proportional only to L_1 and upon grid 12 a voltage proportional only to L_2.

In Fig. 2 the right-hand anode-cathode path of photo-cell 1 is represented by current source i_1 connected to the external circuits through a very high internal resistance 28 of the order of 100 megohms. Similarly, i_2 represents the left-hand path of photocell 4 as a current source in series with internal resistance 29 also of the order of 100 megohms.

In the following analysis, let Φ_1 and Φ_2 be the photoelectric efficiency of cathode portions 2 and 3 respectively, S_1 and S_2 be the fractions of light beams L_1 and L_2 respectively, which fall undesirably S_1 on cathode portion 3 and S_2 on cathode portion 2. Then the cathode emission will be

$$i_1=\Phi_1 L_1(1-S_1)+\Phi_1 L_2 S_2 \text{ for portion 2} \quad (1)$$

$$i_2=\Phi_2 L_2(1-S_2)+\Phi_2 L_1 S_1 \text{ for portion 3} \quad (2)$$

Most of the current i_1 will flow to anode 6, most of i_2 to anode 8 in cell 1, but the portion of each current will be diverted by electrical crosstalk represented in Fig. 2 by resistances 26 and 27. In the case of 5 per cent crosstalk resistances 26 and 27 are each of the order of 2000 megohms or twenty times resistance 28 or 29. In the diagram of Fig. 2 i_{a1} and i_{a2} are the currents actually reaching anodes 6 and 8, respectively. Equations 1 and 2 apply to the steady currents corresponding to unmodulated light beams L_1 and L_2. These equations apply equally to the alternating currents which correspond to modulation of light, it having been assumed that L_1 and L_2 are modulated to the same extent. In what follows, i_1 and i_2 will be taken to be alternating currents, L_1 and L_2 modulated light amplitudes.

In the equations below, each resistance value is identified by the appropriate numerals in Figs. 1 and 2.

Considering the mesh of Fig. 2, one finds the total current to anode **6**:

$$i_{a1}=i_1\frac{R_{26}}{R_{26}+R_{28}}+i_2\frac{R_{29}}{R_{27}+R_{29}} \quad (3)$$

the total current to anode **8**:

$$i_{a2}=i_2\frac{R_{27}}{R_{27}+R_{29}}+i_1\frac{R_{28}}{R_{26}+R_{28}} \quad (4)$$

Multiplying Equations 1 and 3, we find

$$i_{a1}=L_1\left[\frac{\Phi_1(1-S_1)R_{26}}{R_{26}+R_{28}}+\frac{\Phi_2S_1R_{29}}{R_{27}+R_{29}}\right] \quad (5)$$

$$+L_2\left[\frac{\Phi_2(1-S_2)R_{29}}{R_{27}+R_{29}}+\frac{\Phi_1S_2R_{26}}{R_{26}+R_{28}}\right] \text{ approximately}$$

The approximation involves neglecting resistances R_7 and R_9, which are of the order of 1 megohm, and so negligible in comparison with the internal cell resistances R_{28} and R_{29} and with the still greater crosstalk resistances R_{26} and R_{27}.

Simplifying Equation 5, one may write

$$i_{a1}=L_1\Phi_1(1-Q_1)+L_2\Phi_2Q_2 \quad (6)$$

Similarly,

$$i_{a2}=L_2\Phi_2(1-Q_2)+L_1\Phi_1Q_1 \quad (7)$$

And the total cathode current,

$$i_3=i_1+i_2=L_1\Phi_1+L_2\Phi_2 \quad (8)$$

In evaluating the voltage e_1 between grid **11** and ground, it is convenient to consider as positive current flowing toward grid **11** in grid leak **21**, as negative current flowing toward ground in potentiometer **23**. The voltage on grid **11** contributed by i_{a1} is

$$e_{a1}=i_{a1}Z_1$$

where Z_1 is the actual resistance between grid **11** and ground G. Approximately,

$$Z_1=\frac{R_7(R_{21}+R_{24})}{R_7+R_{21}+R_{24}}=\frac{R_7R_{21}}{R_7+R_{21}}$$

since R_{24}, the resistance included between grid and tap **24** on potentiometer **23**, is much smaller than R_7 and R_{21}.

With this approximation,

$$e_{a1}=i_{a1}\frac{R_7R_{21}}{R_7+R_{21}} \quad (9)$$

The voltage contributed by current i_3 in potentiometer **23** is

$$e_3=-i_3\frac{R_{24}R_7}{R_7+R_{21}} \quad (10)$$

to the same approximation as (9). Combining (9) and (10) one finds $e_1=e_{a1}+e_3$, or

$$e_1=\frac{R_7}{R_7+R_{21}}(i_{a1}R_{21}-i_3R_{24}) \quad (11)$$

It is desired that e_1 be independent of L_2. By substituting in (11) the components of i_{a1} and i_3 which depend on L_2, Equations 6 and 8, one finds that L_2 disappears from (11) if

$$L_2\Phi_2Q_2R_{21}=L_2\Phi_2R_{24} \quad (12)$$

that is, if

$$Q_2R_{21}=R_{24} \quad (13)$$

Tap **24** is accordingly selected to provide the value of R_{24} defined by Equation 13.

For convenience in adjustment of tap **24**, likewise of tap **25**, potentiometer **23** should have a resistance greater than, say twice, that of the grid leak R_{21} times the total cross-talk coefficient Q_2 (or Q_1, if these coefficients have nearly the same value).

From (11) and (13) one finds

$$e_1=\frac{R_7R_{21}}{R_7+R_{21}}(i_{a1}-Q_2i_3) \quad (14)$$

Substituting in (14) the L_1 components of (6) and (8), one finds

$$e_1=L_1\phi_1\frac{R_7R_{21}}{R_7+R_{21}}(1-Q_1-Q_2) \quad (15)$$

Adjusting in the same fashion tap **25** on potentiometer **23**, one obtains by similar reasoning for the voltage on grid **12**

$$e_2=L_2\phi_2\frac{R_9R_{22}}{R_9+R_{22}}(1-Q_2-Q_1) \quad (16)$$

The described adjustments of taps **24** and **25** permit the electrical reproduction of light signals L_1 and L_2 independently of each other. In practice, these adjustments are preferably made as follows, since Q_1, Q_2 are usually unknown:

Light L_1 is obscured, and tap **24** is adjusted by trial to minimize the current (now solely due to light L_2) in the output circuit of VI. After this adjustment of tap **24**, L_1 is restored, L_2 is obscured and tap **25** is adjusted to minimize the current due to L_1 in the output circuit of V_2.

Having made these adjustments of taps **24** and **25**, one obtains voltages e_1 and e_2 on grids **11** and **12**, respectively, independent of each other. Each of the voltages e_1 and e_2 is less than it would be were there no crosstalk, in the ratio $1-Q_1-Q_2$ to 1. Thus, the object of this invention is attained.

Those skilled in the art will recognize that grids **11** and **12** may be coupled conductively to anodes **6** and **8**, respectively, and capacitatively to grid leaks **21** and **22**, respectively, provided appropriate changes are made in the supply circuits to tubes **V1** and **V2**, without departing from the spirit of this invention.

In the circuit of Fig. 1 and its symbolic equivalent Fig. 2, the two signal currents which are to be separated are superimposed in greatly differing ratios in different circuit elements. Under the conditions assumed to illustrate the application of this invention, the two currents appear with approximately equal values in potentiometer **23**, but in either anode-cathode path of cell **1** these currents are in the ratio of about 95 to 5. According to the method of this invention, the separation is effected by introducing in series with the normal grid-to-ground voltage of each amplifying tube a voltage of opposing phase and of suitable magnitude derived from potentiometer **23**, to effect cancellation of the undesired component at the expense of cancelling at the same time a small fraction of the desired component.

As a numerical example, assume:

$L_1=L_2=0.01$ lumen (direct current component)
$\Phi_1=\Phi_2=100$ microamperes per lumen
$S_1=S_2=0.02$
$R_7=R_9=1$ megohm
$R_{21}=R_{22}=0.5$ megohm
$R_{28}=R_{29}=95$ megohms
$R_{26}=R_{27}=2000$ megohms

With the above constants, Equation 5 gives

$i_{a1}=i_{a2}=0.936\ L_1+0.064\ L_2$ (direct current component)
$Q_1=Q_2=0.064$

In this case, Equation 13 gives

$$R_{24}=R_{25}=32{,}000 \text{ ohms}$$

Equation 15 gives

$e_1=0.29\ M_1$ volt
$e_2=0.29\ M_2$ volt

where M_1 and M_2 are the modulation factors of light fluxes L_1 and L_2, respectively; e_1 and e_2 are the maximum instantaneous values of the alternating voltages on grids 11 and 12, respectively. Were there no crossstalk, e_1 and e_2 would each be greater than the values given in the ratio $1/1(2\times0.064)$ or 1.15.

The method of this invention is applicable not solely where the undesired voltages are compensated by voltages of the same kind and of appropriate phase and magnitude obtained from a potentiometer introduced between the cell cathode and the ground line. The compensating voltages may be derived from the plate circuits of the amplifying tubes. Such an application of the invention, alternative to that of Figs. 1 and 2, is shown in Fig. 3.

In Fig. 3, plate 15 of V1 is shunted to ground through capacitor 30 in series with resistor 31 and potentiometer 32. Plate 16 of V2 is similarly shunted to ground through capacitor 33 in series with resistor 34 and potentiometer 35. Terminal 24 of grid leak 21 is connected to a tap on potentiometer 35; terminal 25 of grid leak 22 is connected correspondingly to potentiometer 32. Other circuit elements are identically as in Fig. 1. Since the grid and plate voltages of each tube are opposite in phase, the desired and undesired voltage components on the grids have counterparts of opposite phase in the plate circuits, amplified in the same ratio.

In the description of Figs. 1 and 2, it was stated that the resistance of potentiometer 23 should be approximately 2Q times R_{21}. In Fig. 3 the resistance of potentiometers 32 and 35 may be suitably chosen as follows:

The grid voltages, proportional approximately to R_{21} and R_{22}, are amplified to be proportional to these resistances multiplied by

$$\mu\frac{R_{ext.}}{R_{ext.}+R_{int.}}$$

where μ is the amplification factor of the tube and $R_{ext.}$, $R_{int.}$ are the load resistance (through the output transformer) and the internal resistance of the tube, respectively. Therefore, to obtain a compensating voltage proportional to $2Q\times R_{21}$, the resistance of potentiometer 32 should bear to the total resistance $R_{31}+R_{32}$ the ratio

$$\frac{2Q(R_{ext.}+R_{int.})}{\mu R_{ext.}} \text{ to } 1$$

that is,

$$R_{32}=\frac{2Q}{\mu}(R_{31}+R_{32})\frac{(R_{ext.}+R_{int.})}{R_{int.}} \quad (17)$$

$$R_{35}=\frac{2Q}{\mu}(R_{34}+R_{35})\frac{(R_{ext.}+R_{int.})}{R_{int.}} \quad (18)$$

In these formulas R_{32} and R_{35} may be neglected, since they are small compared to R_{31} and R_{34}, respectively.

Resistors R_{31} and R_{34} are chosen of much (say 100 times) higher resistance than the load resistances. As an example, the load resistance of each tube may be 10,000 ohms and the internal tube resistance 20,000 ohms. In this case R_{31} and R_{34} are each suitably 1 megohm. If now $\mu=16$ and $2Q=0.10$,

$$R_{32}=R_{35}=\frac{0.10}{16}\times10_6\times\frac{30,000}{10,000}=18,700 \text{ ohms}$$

Accordingly, 25,000 ohm potentiometers are suitable for R_{32} and R_{35}.

Condensers 30 and 35 must be of negligible impedance compared to R_{31} and R_{34} at the lowest frequency to be transmitted; for the present purpose they are suitably chosen 0.1 microfarad each.

If the load impedance of either tube is not a pure resistance, compensation for its reactive component must be provided in the shunt 30—31—32 (or 33—34—35). This may be done by shunting R_{31} (or R_{34}) with an impedance of the same character as the load impedance, bearing to the latter the same ratio that R_{31} (or R_{34}) bears to the internal tube resistance; other expedients for this purpose will occur to those employing the invention.

The impedance through which voltage is supplied from battery 5 to the tube plates 15 and 16 and to the cell anodes 6 and 8 are readily chosen by one skilled in the art who has before him the characteristics of the amplifying tubes and of the photocell he has elected to use. The grid leaks 21 and 22 are likewise readily chosen; in the illustration (Fig. 1) of the present invention, using the Western Electric 9A photocell and 262B tubes, suitable values are as follows:

$$R_7=R_9=1 \text{ megohm}$$
$$R_{21}=R_{22}=0.5 \text{ megohm}$$
$$C_{13}=C_{14}=0.005\mu f.$$

and the biasing resistors with by-pass condensers 19 and 20, suitably comprise each a resistance of 1000 ohms in shunt with $1\mu f$. It may be desired to take the amplified photocell voltages from plates 15 and 16 of tubes V1 and V2 to subsequent amplifiers; in this case transformers T1 and T2 may suitably be replaced by resistances of about 10,000 ohms. For the circuit of Fig. 3 the same resistors and capacitors are appropriate as for the circuit of Fig. 1. It has already been stated how those employing this invention may choose the resistances of potentiometer 23 of Fig. 1 and of potentiometers 32 and 35 of Fig. 3.

The alternative circuit of Fig. 3 permits the application of the invention to the case of photocells having three or more anodes and a common cathode. How this is accomplished is shown in Fig. 4, where cell 1 has a third anode 36 and an additional cusp 10′. Voltage to anode 36 is supplied from battery 5 through resistor 37. Amplifying tube V3 is connected through capacitor 41 to cell anode 36. Voltage to plate 39 of tube V3 is supplied from battery 5 through the primary of transformer T3, the secondary of which serves to deliver the output of tube V3 to a subsequent circuit, in the same manner as the secondaries of transformers T1 and T2.

Plate 39 of V3 is shunted to ground line G through capacitor 43 in series with resistor 44 and potentiometer 45. The circuit connections of tubes V1 and V2 are identically as in Fig. 3, except that the grid of each of these tubes is provided with an additional grid leak resistor, grid 11 with resistor 52 brought to tap 53 of potentiometer 45, grid 12 with resistor 50 brought to tap 51 of potentiometer 45. Likewise grid 38 of tube V3 is provided with two grid leak resistors, 46 and 48. Resistor 46 is brought to tap 47 of potentiometer 35, resistor 48 to tap 49 of potentiometer 32.

Thus in Fig. 4, the grid of each amplifying tube is enabled to obtain a compensating voltage of proper phase and magnitude from the plate circuits of the other tubes. Each grid separately would, without the compensation provided by this invention, be affected by the desired and undesired voltage components, the latter arising from crosstalk in cell 1 and being of much lower value than the desired component. Potentiometers 32, 35 and 45 are doubly tapped to supply compensating voltages: potentiometer 32 supplies such voltages to grids 12 and 38; potentiometer 35, to grids 11 and 38; potentiometer 45, to grids 11 and 12. While the separate potentiometer settings are not wholly independent, appropriate settings of the taps on each of the three potentiometers can readily be found, since each grid voltage has a desired component greatly predominant over the undesired components.

The resistances of potentiometers 32, 35 and 45 may be determined by the rule already given in the description of Fig. 3. The two grid leak resistors shown in Fig. 4 paralleled on the grids of each tube are, however, each 1 megohm, so that they combine to make the impedance of the grid-to-ground connection of each tube 0.5 megohm as in Figs. 1 and 3.

While the invention has been described with reference to photoelectric cells having in the same glass envelope plural anodes and a cathode common thereto, it will be understood that the method of the invention is not limited to the devices illustrated in the foregoing description. The method of the invention may be applied in the case of multiple electrodes of one polarity, whether positive or negative, with a common electrode of opposite polarity or with physically separate electrodes of opposite polarity connected to a common terminal. The electrodes in question may be those of any type of photosensitive device, and may or may not be housed in a common envelope.

What is claimed is:

1. In a light sensitive circuit including a photoelectric cell having dual anodes and a cathode common to said anodes, a source of light signals associated with the first of said anodes, a second source of light signals associated with the second of said anodes, an amplifying tube individual to each of said anodes, a common ground connection to the cathode circuits of said amplifying tubes, conductive coupling between said common ground connection and the common cathode of said photoelectric cell, coupling between the grid of the first of said amplifying tubes and the first anode of said photoelectric cell, and coupling between the grid of the second of said amplifying tubes and the second anode of said photoelectric cell, means for electrically reproducing said light signals independently of each other, including a grounded potentiometer traversed by currents corresponding to the second of said light signals and a resistive coupling between the grid of the first of said amplifying tubes and a selected tap on said potentiometer.

2. In a light sensitive circuit including a photosensitive device having dual electrodes of one polarity and an electrode of opposite polarity common to said dual electrodes, a source of light signals associated with the first of said dual electrodes, a second source of light signals associated with the second of said dual electrodes, an amplifying tube individual to each of said dual electrodes, a common ground connection to the cathode circuits of said amplifying tubes, conductive coupling between said common ground connection and the common electrode of said photosensitive device, coupling between the grid of the first of said amplifying tubes and the first of said dual electrodes, and coupling between the grid of the second of said amplifying tubes and the second of said dual electrodes, means for electrically reproducing said light signals independently of each other, including a grounded potentiometer traversed by currents corresponding to the second of said light signals and a resistive coupling between the grid of the first of said amplifying tubes and a selected tap on said potentiometer.

3. In a light sensitive circuit including a photoelectric cell having dual anodes and a cathode common to said anodes, a source of light signals individually associated with each of said anodes, means for electrically reproducing said light signals independently of each other, including an amplifying tube individual to each of said anodes, coupling between the grid of each of said tubes and the corresponding one of said anodes, a common ground connection to the cathode circuits of said tubes, a potentiometer connected between said common ground connection and the common cathode of said photoelectric cell, and a resistive coupling between the grid of each of said tubes and a selected tap on said potentiometer.

4. In a light sensitive circuit including a photoelectric cell having dual anodes and a cathode common to said anodes, a source of light signals individually associated with each of said anodes, means as in claim 3 for electrically reproducing said light signals independently of each other, wherein the potentiometer connected between the common ground connection and the common cathode of said photoelectric cell has a resistance of the order of 10 per cent of that of the resistive coupling between the grid of either amplifying tube and the corresponding tap on said potentiometer.

5. In a light sensitive circuit including a photoelectric cell having dual electrodes of one polarity and a common electrode of opposite polarity, a source of light signals individually associated with each of said dual electrodes, means for electrically reproducing said light signals independently of each other, including an amplifying tube individual to each of said duel electrodes, coupling between the grid of each of said tubes and the corresponding one of said dual electrodes, a common ground connection to the cathode circuits of said tubes, a potentiometer connected between said common ground connection and the common electrode of said photoelectric cell, and a resistive coupling between the grid of each of said tubes and a selected tap on said potentiometer.

6. In a light sensitive circuit including dual photosensitive devices having electrically independent electrodes of one polarity and electrically connected electrodes of opposite polarity, a source of light signals individually associated with each of said electrically independent electrodes, means for electrically reproducing said light signals independently of each other, including an amplifying tube individual to each of said electrically independent electrodes, coupling between the grid of each of said tubes and the corresponding one of said electrically independent electrodes, a common ground connection to the cathode circuits of said tubes, a potentiometer connected between said common ground connection and the electrically connected electrodes of said photosensitive devices, and a resistive coupling between the grid of each of said tubes and a selected tap on said potentiometer.

7. In a light sensitive circuit including a photoelectric cell having dual anodes and a cathode

common to said anodes, a source of light signals individually associated with each of said anodes, means for electrically reproducing said light signals independently of each other, including an amplifying tube individual to each of said anodes, coupling between the grid of each of said tubes and the corresponding one of said anodes, a common ground connection to the cathode circuits of said tubes and to the common cathode of said photoelectric cell, a shunt circuit comprising capacitance and resistance in series individually connecting the anode of each of said amplifying tubes to said common ground connection, and a resistive coupling between the grid of each of said tubes and a selected tap on the resistance included in the shunt circuit connecting the anode of the other of said tubes to said common ground connection.

8. In a light sensitive circuit including a photoelectric cell having dual anodes and a cathode common to said anodes, a source of light signals individually associated with each of said anodes, means as in claim 7 for electrically reproducing said light signals independently of each other, wherein each shunt circuit connecting the anode of an amplifying tube to the common ground connection includes a resistor of which the resistance bears to that of the tube load a ratio of the order of 100 to 1, in series with a condenser of which the capacity in microfarads is of the order of one-tenth the resistance in megohms of said resistor.

9. In a light sensitive circuit including a photoelectric cell having dual anodes and a cathode common to said anodes, a source of light signals individually associated with each of said anodes, means as in claim 7 for electrically reproducing said light signals independently of each other, wherein each shunt circuit connecting the anode of an amplifying tube to the common ground connection comprises in series a resistor of which the resistance bears to the resistance of the tube load a ratio of the order of 100 to 1, a condenser of which the capacity in microfarads is of the order of one-tenth the resistance in megohms of said resistor, and a potentiometer of which the resistance is of the order of 5 per cent of that of said resistor.

10. In a light sensitive circuit including a photoelectric cell having plural anodes and a cathode common to said anodes, a source of light signals individually associated with each of said anodes, means for electrically reproducing said light signals independently of each other, including an amplifying tube individual to each of said anodes, coupling between the grid of each of said amplifying tubes and the corresponding one of said anodes, a common ground connection to the cathode circuits of said tubes and to the common cathode of said photoelectric cell, a shunt circuit comprising capacitance and resistance in series individually connecting the anode of each of said tubes to said common ground connection, and resistive coupling between the grid of each of said tubes and a selected tap on the resistance included in each shunt circuit connecting the anode of another of said tubes to said common ground connection.

11. In a light sensitive circuit including a photo-sensitive device having plural electrodes of one polarity and an electrode of opposite polarity common to said plural electrodes, a source of light signals individually associated with each of said plural electrodes, means for electrically reproducing said light signals independently of each other, including an amplifying tube individual to each of said plural electrodes, coupling between the grid of each of said amplifying tubes and the corresponding one of said plural electrodes, a common ground connection to the cathode circuits of said tubes and to the common electrode of said photosensitive device, a shunt circuit comprising capacitance and resistance in series individually connecting the anode of each of said tubes to said common ground connection, and resistive coupling between the grid of each of said tubes and a selected tap on the resistance including in each shunt circuit connecting the anode of another of said tubes to said common ground connection.

12. In a light sensitive circuit including a plurality of photosensitive devices having electrically independent electrodes of one polarity and electrically connected electrodes of opposite polarity, a source of light signals individually associated with each of said electrically independent electrodes, means for electrically reproducing said light signals independently of each other, including an amplifying tube individual to each of said electrically independent electrodes, coupling between the grid of each of said tubes and the corresponding one of said electrically independent electrodes, a common ground connection to the cathode circuits of said tubes and to the electrically connected electrodes of said photosensitive devices, a shunt circuit comprising capacitance and resistance in series individually connecting the anode of each of said amplifying tubes to said common ground connection, and resistive coupling between the grid of each of said tubes and a selected tap on the resistance included in each shunt circuit connecting the anode of another of said tubes to said common ground connection.

13. In a light sensitive circuit including a photoelectric cell having dual anodes and a cathode common to said anodes, together with an amplifying tube individual to each of said anodes, the method of compensating crosstalk between the two anode-cathode paths of said photoelectric cell which comprises introducing into the grid circuit of each of said amplifying tubes a controlled voltage derived from the currents generated in said photoelectric cell opposite in phase but corresponding in magnitude to the crosstalk voltage normally present in said grid circuit.

14. In a light sensitive circuit including a photoelectric cell having plural anodes and a cathode common to said anodes, together with an amplifying tube individual to each of said anodes, the method of compensating crosstalk among the several anode-cathode paths of said photoelectric cell which comprises introducing into the grid circuit of each of said amplifying tubes a controlled voltage derived from the currents generated in said photoelectric cell individually opposite in phase but corresponding in magnitude to each of the crosstalk voltages normally present in said grid circuit.

15. In a light sensitive circuit including a photosensitive device having plural electrodes of one polarity and an electrode of opposite polarity common to said plural electrodes, together with an amplifying tube individual to each of said plural electrodes, the method of compensating crosstalk among the several anode-cathode paths of said photosensitive device which comprises introducing into the grid circuit of each of said amplifying tubes a controlled voltage derived from the currents generated in said photosensitive device individually opposite in phase but cor-

responding in magnitude to each of the crosstalk voltages normally present in said grid circuit.

16. In a light sensitive circuit including a photosensitive device having plural electrodes of one polarity and an electrode of opposite polarity common to said plural electrodes, the method of compensating crosstalk among the several anode-cathode paths of said photosensitive device which consists in neutralizing each crosstalk voltage derived from the currents generated in said light sensitive circuit by a voltage comprising plural components at least one of which is of corresponding magnitude but opposite phase to said crosstalk voltage.

WALTER J. ALBERSHEIM.