

July 26, 1960

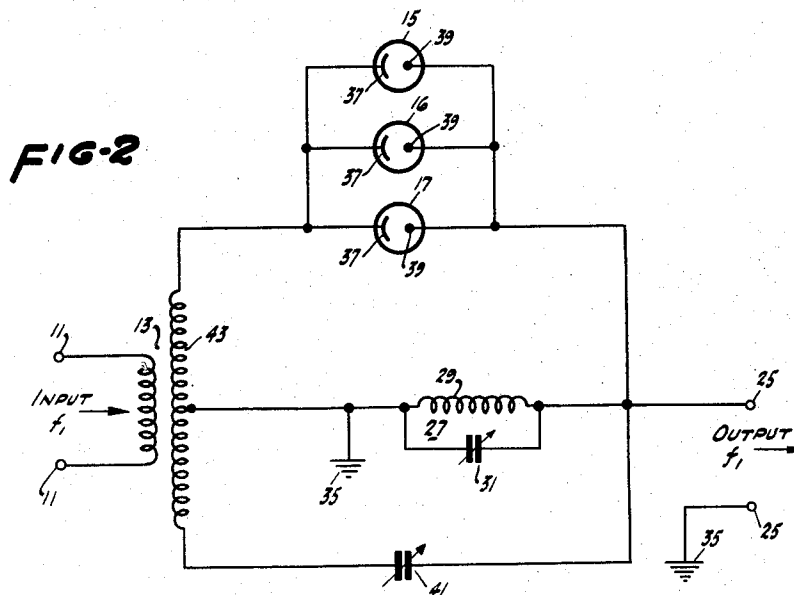
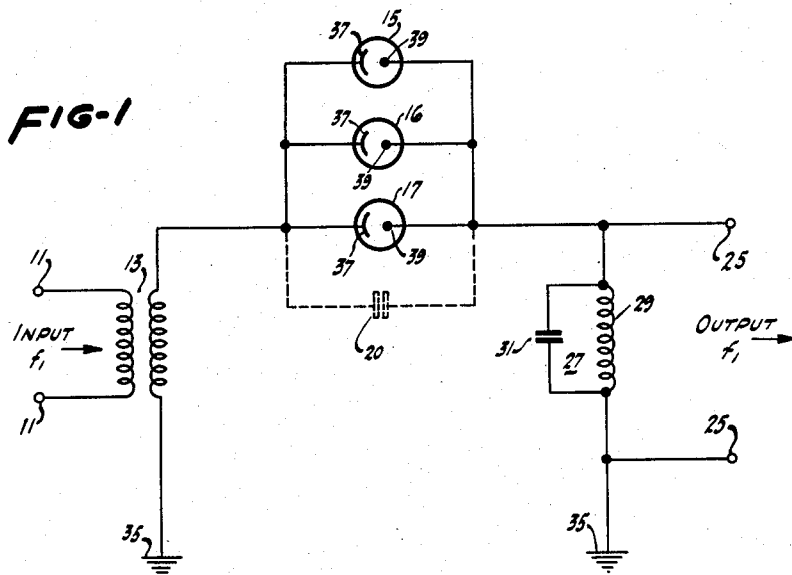
J. B. POWERS

2,946,894

LIGHT CONTROL SIGNAL GENERATOR

Filed Oct. 29, 1957

3 Sheets-Sheet 1



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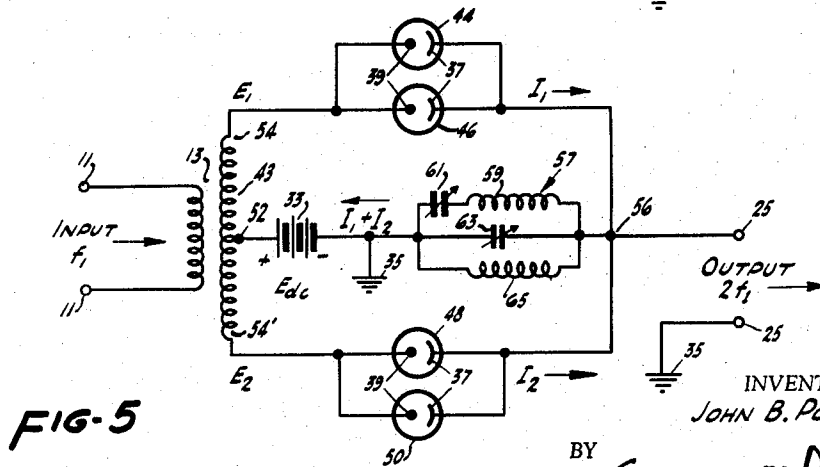
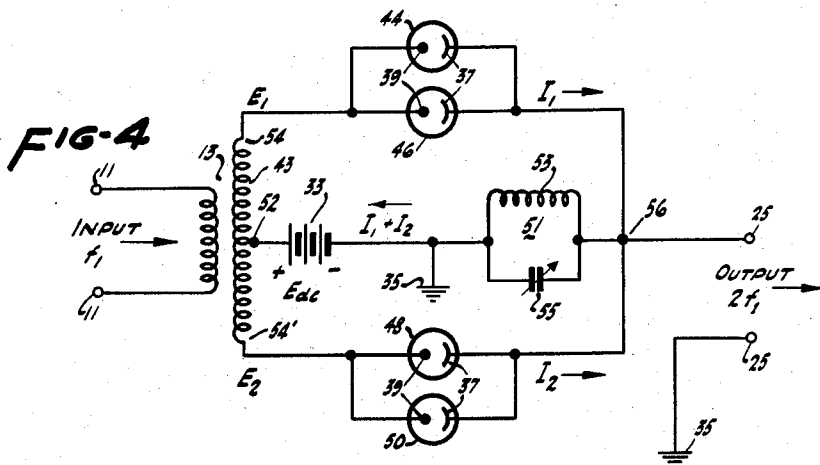
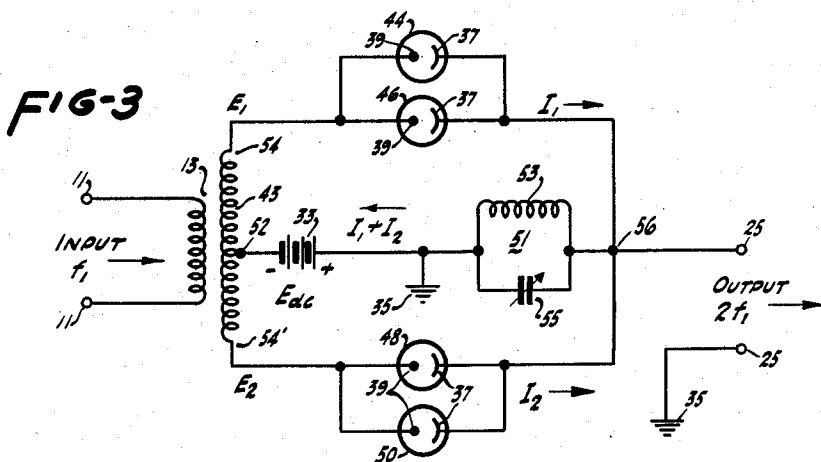
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3 Sheets-Sheet 2



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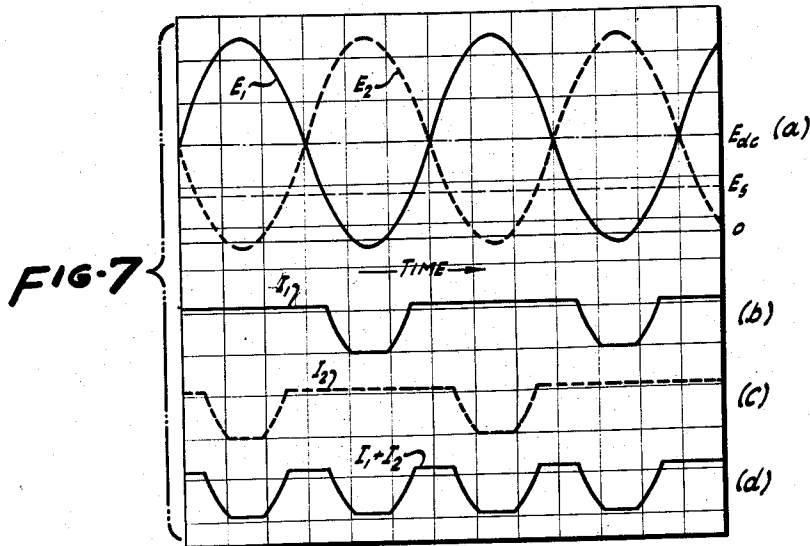
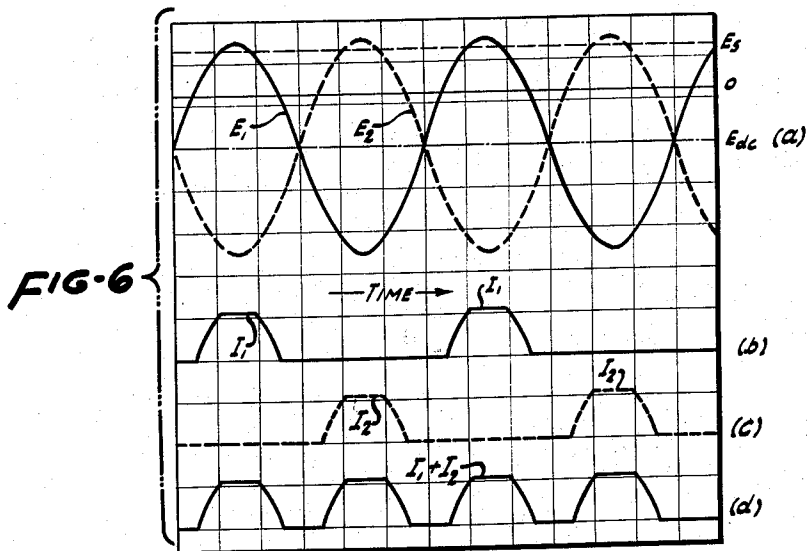
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LIGHT CONTROL SIGNAL GENERATOR

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3 Sheets-Sheet 3



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2,946,894

LIGHT CONTROL SIGNAL GENERATOR

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Filed Oct. 29, 1957, Ser. No. 693,137

11 Claims. (Cl. 250—210)

This invention relates to apparatus particularly adapted for selecting between components according to their color so that objects of different colors or shades may be distinguished one from the other in color sorting.

Particularly in the sorting of fruit, of which lemons are an illustration of a form with which this invention can be used, it is important that the individual fruit pieces be segregated or sorted accurately in accordance with their varying degrees of maturity. The lemons when simultaneously picked, even from a single tree, are usually found to be of various degrees of maturity. Some lemons are of the variety which is known to be far from maturity, such as the dark green lemons; others are lighter green in color and closer to a mature state; others are of the so-called silver variety and quite close to a mature state; while still others are of the yellow variety and truly both ripe and mature. Consequently, while all of these lemons are in harvestable condition, the different degrees of maturity make it desirable to sort and segregate the lemons according to surface coloration, which is the present indication of the actual maturity of the fruit and of the time they can be preserved before marketing.

In accordance with teachings of this applicant, one particularly effective sorting operation by which even closely similar surface color shades may be distinguished has been provided by developing a plurality of signal pulses from which a ratio of the light reflectance of the surface of the object to different selected illuminating wavelengths spaced in the spectrum may be established. To achieve this effect light sensitive translating devices or phototubes are illuminated by light reflected from the objects to be sorted. Output signals of one form are obtained when the objects to be classified are first illuminated individually by light confined to one narrow band located toward one end of the spectrum. Other output signals are developed from the light sensitive translating devices when they are subjected to illumination by light reflected from the same objects when illuminated by light occupying a second narrow band within the spectrum, but which second band appears in a different portion within the spectrum from the first illumination. The light wavelengths to illuminate the objects is then shifted in any appropriate way so that as each object passes an exploring point it is illuminated by each selected light wavelength in sequence. The illuminating light changes from instant to instant by the control of this invention so that the objects are alternately illuminated by substantially monochrome light of different spectral composition. The illuminating light under such conditions is then shifted at any selected rate between the two illuminating substantially monochrome light compositions with at least one exposure or illumination of the object to be sorted at the exploration point with each illuminating light composition. The result is that reflected light from the subject produces output signal energy from the light sensitive devices into which the reflected light falls with at least one output signal occurring during object illumination at each substantially monochrome light composition. In this way the reflect-

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ance of the objects to light at each illuminating wavelength is determined.

The signals serving to control the sorting operation are termed by this applicant to be signals indicative of the index of variation of reflectance, which is also and frequently called the "IVR." Broadly, the index of variation of reflectance is equal to the ratio provided by the difference in signal output from light-sensitive elements illuminated by light reflected from the object when the object is subjected to illumination at two distinct wavelengths of light compared to a signal value which is represented by a constant times the maximum signal, plus the quantity 1 minus the selected constant times the minimum signal, where the selected constant can be chosen or selected as any value in the range between and including each of zero and unity. Mathematically this may be expressed, illustratively, if the maximum signal is assumed to be R_1 , and the minimum signal is assumed to be R_2 , in a form where the index of variation of reflectance (IVR) is represented as

$$\frac{R_1 - R_2}{KR_1 + (1 - K)R_2}$$

Then, if the value of K, for instance, is assumed to equal one-half ($\frac{1}{2}$)

$$IVR = \frac{R_1 - R_2}{R_1 + R_2}$$

If now K is assumed to equal zero, then

$$IVR = \frac{R_1 - R_2}{R_2}$$

Similarly, if K is assumed to equal unity (1), then

$$IVR = \frac{R_1 - R_2}{R_1}$$

Other values of K will provide an index of variation of reflectance (IVR) which can readily and similarly be computed.

In the operation of color sorting devices such as those used to sort lemons wherein the segregation of the components to be sorted is established in accordance with measurements of the index of variation of reflectance, a multiplicity of photoelectric tubes is so located that as each object to be sorted comes in sequence within the exploration region it is practically surrounded by a group of light-sensitive elements or photoelectric tubes so that the photoelectric tubes receive light reflected from all parts of the object, that is, top, bottom, all sides, as well as at various angles. The precise number of photoelectric tubes may vary but there should be a sufficient number that the combined output represents generally the integrated light reflectance over the complete object surface. Then when the object is illuminated by light of different wavelengths (i.e., substantially monochromatic light of different spectral composition) this light is reflected from the object in substantially all directions so that the reflected light is quite independent of the object size, shape, orientation, surface characteristics, or the like. At the same time, since the light is reflected to a multiplicity of photoelectric tubes, the reflected light is measured by the combined output of these phototubes, all or groups of which are connected with their outputs in parallel. For determination of the index of variation of reflectance, each of the signals produced as a result of illumination of the object at a selected light wavelength is subdivided or chopped at a frequency much higher than the rate of shift between the two illuminating wavelengths. This effectively provides distinct signal pulses of amplitude proportional to the light reflectance of the object at the

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particular light wavelength and yet it provides ways by which the desired carrier frequency or chopping frequency can be recovered for the purpose of utilization in the controlling circuit instrumentalities.

In the preferred form of operation, according to this invention, the phototube current produced as a result of object illumination at a selected light wavelength is interrupted or chopped to produce a selected carrier frequency. In order to avoid the simultaneous generation of a spurious and undesired background signal which might occur because of the unavoidable internal capacitance of the phototubes, the phototubes are connected in a bridge circuit. Usually a plurality of parallelly connected phototubes form one arm of a bridge and other phototubes, also parallelly connected, form an adjacent arm of the bridge. The third and fourth arms of the bridge are formed by suitable impedance elements and appropriate operating bias is supplied to the phototubes along the diagonal between the junction of the two bridge arms formed by each of the sets of parallelly connected phototubes and the junction of the two impedance elements which form the third and fourth arms of the bridge. Exciting voltage at one-half of the desired carrier frequency is applied by way of coupling to the impedance elements so that it appears across the opposite diagonal of the bridge whereby, for conditions of bridge balance and in the absence of phototube illumination, no output is developed along the diagonal from which the biasing voltage is applied. At times when light strikes the phototubes current flow is produced therethrough, and current pulses at the frequency of the exciting voltage flow through the bridge arms and thence through the diagonal along which the biasing voltage is applied. However, since the exciting voltage is out-of-phase at opposite ends of the diagonal over which it is applied, there appear in the diagonal of the bridge from which biasing voltage is applied output pulses at double the frequency of the exciting voltage, which pulses are of an amplitude proportional to the reflectance of light from the object at the instantaneous light wavelength at which the object is being illuminated to reflect light therefrom to the phototubes. Any voltage appearing across the bridge diagonal from which biasing voltage is applied by reason of slight bridge unbalance occurs at a frequency an octave removed from the repetition rate of the output current pulses and is easily removed by tuning techniques to be described later.

The device and the bridge circuit accordingly act generally as a full wave rectifier whose output is controlled by light reaching the phototubes. Precise balance of the bridge is not necessary and the effect of the capacity of the phototubes in the two bridge legs is generally neutralized. Appropriate adjustment of the phototube bias and the magnitude of the exciting voltage generally serves to produce voltage saturation in the phototubes during a large fraction of their total conducting periods and to interrupt the flow of current during similar time intervals, thus providing a close approach to a square-wave output.

From the foregoing, one of the objects of the invention is to provide an improved light modulated circuit wherein a carrier signal is produced whose amplitude is a measure of light intensity.

Another object of the invention is to provide improved circuitry for light modulated signal generators used in color sorting operations.

A further object of the invention is to nullify the capacitive effects of phototubes in color sorting operations where the phototube outputs represent the signals from which control voltages or ratios are derived.

Other objects and advantages of the invention will become apparent from a consideration of the accompanying drawings in which

Fig. 1 represents schematically one circuit for trans-

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ferring an input carrier frequency to an output circuit with the phototube serving as the keying instrumentality;

Fig. 2 is a diagrammatic showing of one form of bridge circuit wherein a plurality of phototubes is parallelly connected to form one arm of the bridge and wherein the bridge circuit is capacitively balanced;

Fig. 3 is a circuit diagram of a form of the invention wherein the light modulated circuit comprises a bridge circuit in which parallelly connected phototubes comprise at least two arms of the bridge and wherein negative bias is applied to the phototube anodes.

Fig. 4 is a circuit somewhat similar to the showing of Fig. 3 where the phototubes, when illuminated, serve to determine the amplitude of the output signal and wherein positive bias is supplied to the phototube anode elements;

Fig. 5 is a circuit diagram similar to Fig. 4 but wherein the output is derived across a different form of tuned circuit; and

Figs. 6 and 7 are series of curves to explain the operation of the circuits of Figs. 3 and 4 respectively.

Referring now to the drawings for a further understanding of the invention and first to the circuit of Fig. 1, exciting voltage at a selected frequency f_1 is applied at a pair of input terminals 11 and fed through a coupling transformer 13 to a multiplicity of phototubes 15, 16, 17, etc., and thence to a tuned output circuit 27 comprising the inductance element 29 and its shunting capacity 31. The output circuit 27 is tuned to resonance at the frequency f_1 and the voltage developed thereacross appears at the output terminals 25. With this connection the phototubes are polarized to conduct photoemissive current during negative half-cycles of the input voltage and to prevent current flow during positive half-cycles. Accordingly, if light reaches any of the phototubes 15, 16, 17, etc. to cause photoemission therein, a series of current pulses at a repetition rate equal to f_1 flows through the resonant circuit 27 and produces at the output terminals 25 a carrier voltage at the frequency f_1 whose amplitude is a measure of the total photoemitted current. The phototubes generally operate as half-wave, light-modulated rectifiers.

The phototubes 15, 16, 17, etc., are placed relative to the objects to be explored in such relationship that reflected light from all regions of the object (that is, its top, bottom, all sides and various angles) reaches the phototubes which then are illuminated by light reflected from all regions of the illuminated object with the reflected light controlling the current flow therethrough. The resultant current at the output is determined by the average or integrated output of all of the phototubes and thus can represent the reflected light over substantially the whole object surface.

As the combination has been shown by Fig. 1, the capacity of the group of phototubes is schematically represented in dotted outline by the capacity element 20. Due to the fact that the input frequency f_1 may have a relatively high value, for instance something of the order of 65 kc., as an illustration, the phototube capacity is often sufficient, irrespective of whether or not the phototubes are illuminated, to provide a transfer path between the input transformer 13 and the output terminals 25. Thus a continuous background voltage at the frequency f_1 and independent of phototube illumination is produced across the output terminals 25 which may exceed by thousands or even hundreds-of-thousands of times the output voltage produced at the terminals 25 by photoemissive action. Under conditions of low illumination of the phototubes this background voltage effectively masks the light-modulated output signal and the device generally fails to perform as a light-modulated signal generator.

One way in which the signal masking effect of the capacity-coupled background voltage can be substantially

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reduced is shown in the circuit modification of Fig. 2. Here the phototubes 15, 16, 17, etc. form one leg of a bridge circuit, an adjacent leg of which is formed by the capacity element 41 sufficient in magnitude to balance the phototube capacity for the non-illuminated condition thereof. The two other legs of the bridge circuit are formed from an impedance element 43 which is tapped at its center point. One of the outer terminals of the impedance element 43 is connected to the phototubes and the other terminal is connected to one terminal of the balancing capacity 41.

With the arrangement of Fig. 2 an output signal voltage is generated across the circuit 27 made resonant to the frequency f_1 by the action thereon of current pulses produced by the combined action of light reflected from the object and exciting voltage from the transformer 13 on the phototubes in the same manner as that described above for the circuit of Fig. 1. This output signal voltage of frequency f_1 appears at output terminals 25. However, in this case current from the input transformer 13 reaching the resonant circuit 27 through the internal capacity of the phototubes is substantially cancelled by current of opposite polarity coupled from the transformer to the resonant circuit through the balancing capacity 41. This is due to the fact that the potentials at the outer ends of the inductive element 43, of which one connects to the phototubes and the other to the capacity 41, are of opposite polarity.

Clearly the degree to which the bridge arrangement of the circuit of Fig. 2 is effective in suppressing the capacity-coupled background voltage at the output terminals 25 is dependent on the preciseness of balance of the bridge. In practice, use of the circuit of Fig. 2 in place of the circuit of Fig. 1 can result in a reduction of background voltage by a factor of 1000 or even 10,000. Even with a reduction of this magnitude it is found that the minimum practical residual background voltage attainable with the circuit of Fig. 2 is still of such magnitude as to effectively mask the output signal due to photoemission under conditions of low illumination of the phototubes.

By the form of the invention shown in Fig. 3 the effect of phototube capacity is balanced out by other phototubes and wherein any residual capacity-coupled background voltage appearing at the output terminals 25 occurs at a frequency an octave removed from the frequency of the desired signal produced by the action of light on the phototubes. In this case the desired signal is readily separated from the capacity-coupled background voltage by the tuned output circuit. The circuit which is schematically represented is so arranged that one leg of the bridge comprises a plurality of parallelly connected phototubes 44 and 46, of which only two are shown for convenience of illustration. The adjacent leg of the bridge comprises additional parallelly connected phototubes 48 and 50, of which also only two are shown for illustration convenience. The phototubes having substantially the same capacity serve as a capacity balance on the bridge. In this instance the input signal frequency f_1 is also supplied at the input terminals 11 and fed through the input transformer or coupling 13 to the secondary formed by the impedance element 43, of which equal portions connect between a midpoint 52 and the phototubes 44 and 46 on the one end and phototubes 48 and 50 on the other end. Bias to the phototubes is supplied by a source of direct current 33 connected between ground 35 and the midpoint 52 of inductance element 43. The input signal frequency is thus supplied across the diagonal of the bridge between the connection of the outer end 54 of the inductive element 43 and the phototubes 44 and 46 and the connection of the second outer end 54' of the inductance 43 and the phototubes 48 and 50.

Output voltage is derived across the diagonal of the bridge between ground 35 (effective as if at the point 52) and the junction point 56 of the parallelly connected

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phototubes 44 and 46 and the second group of parallelly connected phototubes 48 and 50. In this diagonal of the bridge there is included a tuned circuit 51 comprising parallelly connected inductance elements 53 and the capacity elements 55. The circuit 51 in this instance is tuned to twice the input frequency or to a frequency value of $2f_1$. Voltage developed across this tuned circuit between points 56 and 35 appears at the output terminals 25. In this form of showing the phototubes have their anode elements 39 biased negatively by the direct current source 33. The circuitry of Fig. 4 is generally similar to that disclosed by Fig. 3 except that in this instance the anode elements 39 of the phototubes are biased positively by the source 33, as indicated on each of the figures by the plus and minus signs.

Considering now the diagrammatic showings of Figs. 6 and 7 it will be observed that the curves of Fig. 6 are related to the operation of the bridge circuit disclosed by Fig. 3 while the curves of Fig. 7 are related to the bridge circuit operation as described by Fig. 4. In each instance it will be noted that the input frequency f_1 is applied through the coupling transformer in a way such that voltage E_1 at the end 54 of the inductive element 43 is 180° out-of-phase with respect to the voltage E_2 available at the outer point 54' of the inductive element 43. The amplitude of the impressed voltage wave occurring at the frequency f_1 is represented on Fig. 6 as being of a value represented between the crest of the wave E_1 measured to the dot-dash line E_{dc} . The zero potential is represented by the line marked zero and the biasing value effective in the negative sense with respect to the phototubes 44, 46, 48 and 50 is represented on Fig. 6 by the difference between zero and E_{dc} so that the impressed voltage wave oscillates about a steady state value represented by the dot-dash E_{dc} . In this figure and the upper portion thereof, designated by the curve (a), the dash line E_s represents the voltage required to establish a condition of voltage saturation within the phototubes. E_s is the value of phototube polarizing voltage above which the phototube current is a function of illumination only, which illumination may, for instance, be substantially monochromatic light of the maximum wavelength provided for the illumination. It will be noted from the consideration of portion (a) of Fig. 6 that the voltage wave E_1 exceeds the saturation value E_s of the phototubes in the portion of the wave which crosses the line E_s . The current through the phototubes 44 and 46 designated by I_1 and measured from zero value is shown by the curve (b) and it will be seen that for a substantial portion of each cycle of the impressed input frequency wave occurring at the frequency f_1 no output results due to the impressed voltage E_1 .

Similarly, for the phototubes 48 and 50 which receive the impressed voltage E_2 shown by the dash line (a) in Fig. 6 the current output, designated as I_2 , is represented by a dash line on the curves of Fig. 6 designated (c). The current pulses I_2 , like the current pulses I_1 , occur at the frequency f_1 of the impressed input and since these currents add in the tuned circuit 51 in the bridge diagonal across which the output terminals 25 are connected, it will be observed from the curve (d) of Fig. 6 that the total output for the illuminated condition of the phototubes 44, 46, 48 and 50, etc. is represented by the curve $I_1 + I_2$, and that the pulses of current occur at twice the frequency of the impressed wave f_1 .

From the curves (b) and (c) and (d) of Fig. 6 it will be observed that a portion of each curve is flattened out at the top which indicates that the phototubes have reached a saturation state, as indicated. The curve (d) of the group represents the summation of the curves I_1 and I_2 , designated on the figure as curves (b) and (c) so that the pulses $I_1 + I_2$ occur at twice the frequency of either of the pulses developed under the control of the applied voltage waves E_1 and E_2 . This represents one state of illumination of the phototubes and it will be under-

stood that other light activation will provide different amplitude outputs.

With the circuit arrangement as provided by the poling of the source 33, as in Fig. 4, the type of operation exemplified by the curves of Fig. 7 apply. From Fig. 7 it will be appreciated that the voltage waves E_1 and E_2 represent the input frequency wave f_1 , as instantly available at the ends 54 and 54' of the impedance element 43, for instance. These curves, as are the curves of Fig. 6, are drawn to show that the alternating current components of the input voltages E_1 and E_2 are in opposite time phase. The circuit arrangement of Fig. 4 provides, in contrast to that of Fig. 3 that the biasing voltage represented by the level E_{dc} shown as the dash-dot line on curve (a) is positive so that saturation occurs within the phototubes 44, 46, 48 and 50 at a level shown as E_s plotted with respect to the zero line 0. Under the circumstances output current from the phototubes will flow at all portions of the wave except that represented by the period of time when the activating wave at the frequency f_1 dips below the line of zero potential which can be seen from the curves (b) and (c) so that the output currents I_1 and I_2 respectively are generated when voltage waves E_1 and E_2 are applied and the phototubes are illuminated. The combined output from the two waveforms is designated also in Fig. 7 by the curve (d). As in the type of operation depicted by the curves of Fig. 6, the total output current consists of a series of unidirectional pulses occurring at a repetition rate equal to $2f_1$.

It will be observed that there is a slight advantage to be offered from the form of operation where the positive polarity voltage is applied to the phototube anodes because the waveform of the current pulses in curve (d) of Fig. 7 produces higher impulse values than those of curve (d) of Fig. 6 and thus produces a somewhat higher output signal voltage for a given exciting voltage and phototube illumination. The type of operation is, however, generally optional and for some purposes one form offers advantages as compared to the other.

In the refinement of the invention exemplified by the circuit of Fig. 5 the voltage source 33 is poled with respect to the phototubes in a manner similar to that shown by Fig. 4. However, additional advantage is gained from the arrangement of Fig. 5 in that the resonant load circuit has been modified to provide an extremely low impedance path to ground for any capacity-coupled currents at the frequency f_1 which flow through the load circuit by reason of slight unbalance of the bridge circuit. The arrangements of circuits shown by Figs. 3 and 4 provide that the tuned output circuit 51 comprising the inductance elements 53 and the capacity element 55 is tuned to a frequency $2f_1$ which is twice the input frequency, resulting of course from the fact that the output pulses as shown by portions (d) of each of Figs. 6 and 7 occur at double the frequency of either the pulses I_1 , as per curve (b) or the pulses I_2 , as per curve (c). In the circuit of Fig. 5 the output is derived across the bridge diagonal between similar connections but is derived across a connection of a plurality of capacitive and inductive elements connected in such a way that one inductive and capacitive path is tuned to series resonance at the input frequency f_1 and the combination as a whole is tuned to parallel resonance at the double frequency $2f_1$. In this way most of the undesired frequencies are eliminated from the output available at the output terminal points 25.

Considering specifically the circuitry of Fig. 5 the output pulses are derived across the diagonal between the point 56 and ground 35, as in Figs. 3 and 4. The combination of inductance and capacitance elements forming the network 57 consists of the inductor 59 and the series connected capacitor 61 connected between point 56 and ground 35. These elements tune in series resonant fashion to the input frequency f_1 . Then, by means of the combined effect of the series resonant path 59, 61 and its shunting condenser or capacitor 63 and shunting induc-

tor 65, the combination as a whole is made parallel resonant to the double frequency $2f_1$. As the arrangement is shown, of course, the dc path is provided at all times through the inductive element 65. However, it will be appreciated that various combinations of inductance and capacitance may be used to effect the desired end result.

It will be clear from the foregoing descriptions that the circuits of Figs. 3, 4 and 5 will be operative with the connections to each bank of phototubes interchanged. Thus, in any of these circuits the ends 54 and 54' of the impedance element 42 can be connected to the cathodes of phototubes 44 and 46 and the phototubes 48 and 50 respectively and the anodes of all phototubes may be connected to point 56. With this connection and with suitable adjustment of the biasing voltage from the source 33, the circuit of Fig. 3 will perform in the manner described above for the circuits of Figs. 4 and 5, and the circuits of Figs. 4 and 5 will perform in the manner described for the circuit of Fig. 3. Furthermore, the phototube biasing voltage may be obtained in any convenient way such as, for instance, connecting the biasing source 33 between the resonant circuit 51 and the ground point 35 instead of in the position shown, without in any way affecting the operation of the circuits.

It will be further recognized that the circuits of Figs. 3, 4 and 5 will perform generally as described above to produce output signals at twice the frequency of the applied exciting voltage even when the biasing voltage is completely removed such as by short-circuiting the biasing source 33. In this case, the duration of individual pulses of the currents I_1 and I_2 in the two photosensitive arms of the bridge will be equal to one-half the period of the exciting voltage as in the circuits of Figs. 1 and 2 but, in contradistinction to the circuits of Figs. 1 and 2, the pulse repetition rate of the total output current will be equal to $2f_1$. The use of a biasing voltage as indicated in Figs. 3, 4 and 5 is usually preferable to operation without bias since the duration and shape of the output current pulses can thereby be controlled to maximize the component of the output current occurring at the frequency $2f_1$. Occasionally, however, it is desirable to eliminate the biasing source for purposes of circuit simplification.

Having now described the invention, what is claimed and is desired to be secured by Letters Patent is the following:

1. A light-controlled signal generator comprising a bridge circuit including a pair of photoemissive cells adapted for illumination by a single light source and connected in series opposition to form two adjacent bridge arms and a pair of substantially equal impedance elements connected in series therewith to form a closed circuit, means to apply an oscillating voltage of frequency f across the bridge diagonal spanning the connected impedance elements, and means to derive at the other bridge diagonal a signal of frequency $2f$ controlled in amplitude by light impinging on the photosensitive surfaces.

2. The device claimed in claim 1 including, in addition, means for applying on both photoemissive cells a common biasing voltage lower in magnitude than the amplitude of the applied oscillating voltage and of a polarity to promote current flow in the photoemissive cells with illumination thereof.

3. The device claimed in claim 1 including, in addition, means for applying on both photoemissive cells a common biasing voltage lower in magnitude than the amplitude of the applied oscillating voltage and of a polarity to oppose current flow in the photoemissive cells with illumination thereof.

4. A light controlled signal generator comprising a bridge circuit including a pair of impedance elements series connected to form two adjacent bridge arms and light-sensitive means connected thereto to form the other

two adjacent bridge arms, each light-sensitive means being adapted to be modulated by light from a common light source, means for applying a common biasing voltage upon the separate light-sensitive means, means to apply an oscillating voltage of frequency f and of an amplitude greater than the bias voltage to each bridge arm including the impedance elements with the polarity of the applied voltage being instantaneously of opposite phase at the junction of each impedance element and the light-sensitive means of the adjacent bridge arm, and means to derive at the bridge diagonal between the junction of the light-sensitive means forming adjacent arms of the bridge and the junction of the impedance elements forming the bridge arms a signal of a frequency of $2f$ modulated in amplitude by light impinging upon the light-sensitive means to determine the current flow therethrough.

5. A light controlled signal generator comprising a bridge circuit including a pair of impedance elements series connected to form two adjacent bridge arms and a plurality of parallelly connected light-sensitive means connected to form each of the other two adjacent bridge arms, each light-sensitive means being adapted to be modulated by light from a common light source, means for applying a common biasing voltage upon all of the light-sensitive means, means to apply an oscillating voltage of frequency f and of an amplitude greater than the bias voltage to each bridge arm including the impedance elements with the polarity of the applied voltage being instantaneously of opposite phase at the junction of each impedance element and the light-sensitive means of the adjacent bridge arm, and means to derive at the bridge diagonal between the junction of the light-sensitive means forming adjacent arms of the bridge and the junction of the impedance elements forming the bridge arms a signal of a frequency $2f$ modulated in amplitude by light impinging upon the light-sensitive means to determine the current flow therethrough.

6. A light controlled signal generator comprising a bridge circuit including a pair of series connected impedance elements forming two adjacent arms and a plurality of unilaterally conducting light-sensitive means connected to form the other two adjacent arms, said light-sensitive means each having a photosensitive cathode and an anode, means for applying a common biasing voltage upon all of the light-sensitive means with the bias of a polarity to promote current flow with illumination, means to apply to the impedance elements an oscillating voltage of frequency f and of an amplitude greater than that of the bias to cause a periodic interruption of current flow through the light-sensitive means with illumination thereon, and means to derive at the bridge diagonal between the junction of the light-sensitive means forming adjacent arms of the bridge and the junction of the impedance elements forming the other bridge arms a signal of a frequency $2f$ modulated in amplitude by light impinging upon the light-sensitive means to determine the current flow therethrough.

7. A light controlled signal generator comprising a bridge circuit including a pair of series connected impedance elements forming two adjacent arms and a plurality of unilaterally conducting light-sensitive means connected to form the other two adjacent arms, said light-sensitive means each having a photosensitive cathode and an anode, means for applying a common biasing voltage upon all of the light-sensitive means, with the bias of a polarity to inhibit current flow with illumination, means to apply to the impedance elements an oscillating voltage of frequency f and of an amplitude greater than that of the biasing voltage to permit current flow through the light-sensitive means during portions of the cycle when the bias voltage is overcome and during illumination of the light-sensitive means and thereby to develop across the bridge diagonal between the junction of the impedance elements a resultant voltage of a

frequency $2f$ modulated in amplitude by light impinging upon the light-sensitive means to determine the current flow therethrough.

8. A light-controlled signal generator comprising a bridge circuit including a pair of photoemissive cells adapted for illumination by a single light source and connected in series opposition to form two adjacent bridge arms and a pair of substantially equal impedance elements connected in series therewith to form a closed circuit, means to apply an oscillating voltage of frequency f across the bridge diagonal spanning the connected impedance elements, means to derive at the other bridge diagonal a signal of frequency $2f$ controlled in amplitude by light impinging on the photosensitive surfaces, and an oscillatory circuit parallel resonant at the frequency $2f$ connected in the bridge diagonal extending between the junction of the connected photoemissive cells and the junction of the connected impedance elements.

9. A light-controlled signal generator comprising a bridge circuit including a pair of photoemissive cells adapted for illumination by a single light source and connected in series opposition to form two adjacent bridge arms and a pair of substantially equal impedance elements connected in series therewith to form a closed circuit, means to apply an oscillating voltage of frequency f across the bridge diagonal spanning the connected impedance elements, means to derive at the other bridge diagonal a signal of frequency $2f$ controlled in amplitude by light impinging on the photosensitive surfaces, and a plurality of capacitive and inductive elements connected in the bridge diagonal between the junction of the connected photoemissive cells and the junction of the connected impedance elements, the said combination of capacitive and inductive elements being series resonant at the frequency f and being parallel resonant at the frequency $2f$.

10. A light controlled signal generator comprising a bridge circuit including a pair of impedance elements series connected to form two adjacent bridge arms and light-sensitive means connected thereto to form the other two adjacent bridge arms, each light-sensitive means being adapted to be modulated by light from a common light source, means for applying a common biasing voltage upon the separate light-sensitive means, means to apply an oscillating voltage of frequency f and of an amplitude greater than the bias voltage to each bridge arm including the impedance elements with the polarity of the applied voltage being instantaneously of opposite phase at the junction of each impedance element and the light-sensitive means of the adjacent bridge arm, means to derive at the bridge diagonal between the junction of the light-sensitive means forming adjacent arms of the bridge and the junction of the impedance elements forming the bridge arms a signal of a frequency of $2f$ modulated in amplitude by light impinging upon the light-sensitive means to determine the current flow therethrough, and an oscillatory circuit parallel resonant to the frequency $2f$ connected in the bridge diagonal between the junction of the connected light-sensitive means and the junction of the connected impedance elements.

11. A light controlled signal generator comprising a bridge circuit including a pair of impedance elements series connected to form two adjacent bridge arms and light-sensitive means connected thereto to form the other two adjacent bridge arms, each light-sensitive means being adapted to be modulated by light from a common light source, means for applying a common biasing voltage upon the separate light-sensitive means, means to apply an oscillating voltage of frequency f and of an amplitude greater than the bias voltage to each bridge arm including the impedance elements with the polarity of the applied voltage being instantaneously of opposite phase at the junction of each impedance element and the light-sensitive means of the adjacent bridge arm, means to derive at the bridge diagonal between the junction of

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the light-sensitive means forming adjacent arms of the bridge and the junction of the impedance elements forming the bridge arms a signal of a frequency of $2f$ modulated in amplitude by light impinging upon the light-sensitive means to determine the current flow there-through, and a plurality of capacity and inductive elements connected in the bridge diagonal between the junction of the photosensitive elements and the junction of the impedance elements, the said combination of capacity and inductance elements being series resonant to the frequency f and being parallel resonant to the frequency $2f$.

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