Oct. 29, 1940. A. W. BARBER 2,219,676

LIGHT MODULATION SYSTEM

Filed Dec. 15, 1937

Fig. 1.

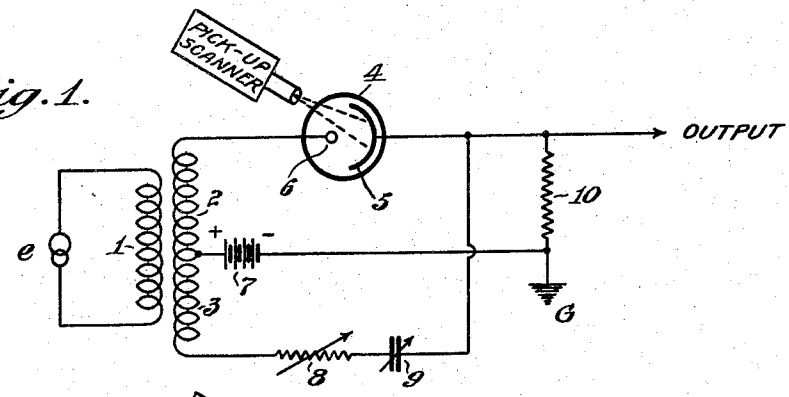


Fig. 2.

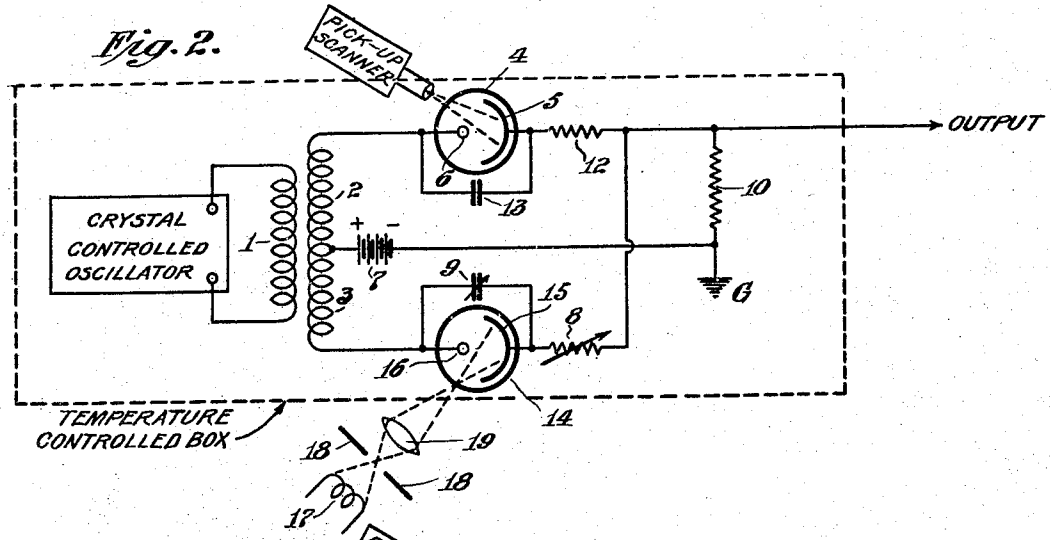
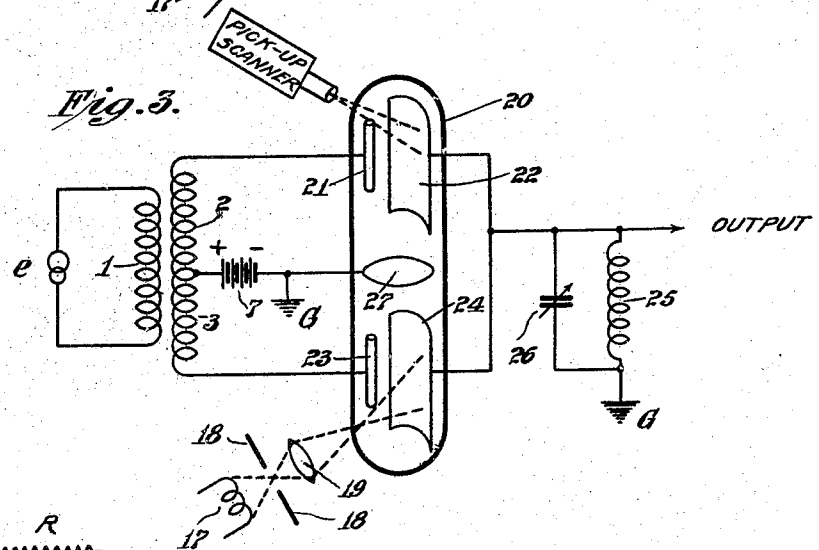
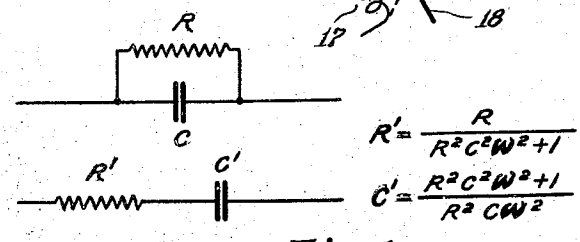


Fig. 3.





$$R' = \frac{R}{R^2C^2W^2+1}$$

$$C' = \frac{R^2C^2W^2+1}{R^2CW^2}$$

Fig. 4.

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LIGHT MODULATION SYSTEM

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5 Claims. (Cl. 179—171.5)

My present invention relates to improvements in photo-electric systems. More particularly it concerns a method of, and means for, modulating an alternating current by means of a photo-electric cell receiving light from a television scanner or the like.

One object of my invention is to provide a means of modulating an alternating current by means of a photo-electric cell actuated by light from a television scanner or other source of varying light impulses. Another object is to reduce the variations in the modulating system due to frequency and temperature changes. Another object is to improve the sensitivity and linearity of such modulating systems.

In television, facsimile and other systems employing a photo-electric cell to convert light variations into electrical currents it is often advantageous to modulate a carrier current wave directly by means of the photo-electric cell rather than to generate simple currents of the same frequency as the light variations. Since, except for very low frequencies, the resistive impedance of the photo-electric cell is usually high compared to the capacitative impedance, it is necessary to balance out capacity currents in order to obtain large percentages of modulation due to resistance variations. Systems of this type have been used in connection with facsimile pick-ups employing audio frequency currents modulated by a photo-electric cell and simple balance circuits. For television, however, I have found it necessary to modulate radio frequency currents and, on account of the greatly increased capacitative currents, to refine the balance circuits. I have found several ways in which more accurate balance may be obtained and more stable maintenance of the balance once it is obtained. One of the difficulties encountered in maintaining balance is due to frequency drift in the radio frequency supply and to changes in the photo-electric cell and balance circuit constants due to temperature effects.

My system overcomes these difficulties to a large extent. Frequency stability is obtained by employing a crystal controlled oscillator. Stability of the photo-electric cell and balance circuits is obtained by means of temperature control of the system and a photo-electric cell in the balance circuit. A special double photo-electric cell may also be used in which one section acts as a modulator and the second section acts as a balance circuit. I have found that the addition of a direct current bias to the photo-electric cell circuit increases its sensitivity and linearity of modulation.

The novel features characterizing my present invention are set forth in particular in the appended claims. The organization and method of operation of the invention itself will best be understood by reference to the following description taken in connection with the drawing in which I have indicated by means of circuit diagrams how my invention may best be carried into effect.

In the drawing:

Fig. 1 shows a simple circuit embodying features of my invention.

Fig. 2 shows a modulating circuit embodying further means of carrying out my invention.

Fig. 3 shows a modulating circuit embodying further means of carrying out my invention.

Fig. 4 shows a fragmentary circuit useful in explaining the operation of features of my invention.

Fig. 1 shows a modulating system in which *e* is a source of alternating current voltage. For facsimile the frequency of this source may be of the order of 2,000 cycles per second and for television of the order of 500,000 to 10,000,000 cycles. For other uses the frequency will be determined by the use. A convenient way to couple the voltage *e* to the modulating circuit is by means of the transformer comprising primary winding 1 and the coupled secondary windings 2 and 3. One end of each of the secondary windings 2 and 3 is connected to the positive end of polarizing battery 7. The other end of winding 2 is connected to anode 6 of photo-electric cell 4 and the other end of winding 3 is connected to a balance circuit consisting of variable resistor 8 in series with variable condenser 9. The side of condenser 9 away from resistor 8 is connected to cathode 5 of photo-electric cell 4 and to one end of output load resistor 10. The other end of resistor 10 and the negative end of battery 7 are connected to the ground point G. The windings 2 and 3 are in such a direction that the photo-electric cell end of winding 2 and the resistor end of winding 3 are of opposite instantaneous polarity. Since one end of each winding 2 and 3 is connected to one end of resistor 10 and ground, the output end of resistor will receive current from winding 2 thru the photo-electric cell impedance and current of opposite phase from winding 3 thru the series impedance of resistor 8 and condenser 9. If the voltages across coils 2 and 3 are of equal magnitude and opposite phase, the net current thru resistor 10 will be

zero when the series circuit consisting of resistor 8 and condenser 9 is made equivalent to the parallel circuit consisting of the photo-electric cell capacity and resistance. Fig. 4 shows a parallel circuit R and C and the equivalent series circuit R′ and C′. If RC represents the photo-electric cell and R′C′ the balance circuit, then balance will exist with no current thru resistor 10 when resistor 8 (R′) equals

$$\frac{R}{R^2C^2\omega^2+1}$$

and condenser 9 (C′) equals

$$\frac{R^2C^2\omega^2+1}{R^2C^2\omega^2}$$

where $\omega=2\pi f$ and f is the frequency of voltage e. I have found in cases where the photo-electric cell capacity is small that it is advantageous to reduce the voltage supplied of winding 3 by reducing the number of turns. This reduced voltage requires an increase in capacity 9 and a reduction in resistor 8 which leads to easier manipulation of the balance circuit. The coupling between winding 1 and the windings 2 and 3 is preferably very close as otherwise the two output currents may not be exactly 180° out of phase.

Thus with the voltages supplied to the photo-electric cell and its balance circuit substantially unequal the phase angle of the balance circuit should be the same as the phase angle of the photo-electric cell impedance but the impedance of the balance circuit should be made equal to the impedance of the photo-electric cell divided by the ratio of the larger of the applied voltages to the smaller of the applied voltages. If this requirement is met it will be evident that the photo-electric cell and balance circuit currents will be equal in phase and magnitude at the particular value of light on the photo-electric cell at which the balance adjustment is made.

When light variations from a "pick-up scanner" are received by the photo-electric cell 4, the resistance of the cell varies in accordance with the light variations upsetting the circuit balance. The unbalance currents thru the photo-electric cell flow thru resistor 10 establishing a voltage drop which varies in accordance with the light variations. Resistor 10 should be large of the order of hundreds of thousands of ohms or megohms. In the case of a high frequency carrier as must be used in television, it is advantageous to replace resistor 10 with a choke coil or a tuned circuit since at high frequencies the capacity across resistor 10 will seriously shunt its impedance. The choke or tuned circuit acts to maintain a high output circuit impedance in the presence of shunting capacities.

Battery 7 is useful in polarizing photo-electric cell 4 to a linear part of its characteristic. Battery 7 also increases the sensitivity of the modulating action since the sensitivity of most photo-electric cells is a function of the instantaneous voltage drop across them. The polarity of battery 7 and cathode and anode of cell 4 may be reversed without departing from the spirit of the invention. Voltage e and the ratio of transformation between windings 1 and 2 should be so chosen that the drop across cell 4 is always within the linear part of its characteristic.

The fundamental circuit of Fig. 2 is the same as that of Fig. 1 and the theory of operation is the same. However, several improvements over Fig. 1 are shown here. Since the series equivalent R′C′ balance circuit as explained in connection with Fig. 1 depends on f, it is important that the frequency of e be constant or the balance will change. I have found that a "crystal controlled oscillator" as shown in Fig. 2 provides the necessary stable frequency for the voltage source. The same three windings may be used by connecting primary 1 to the "crystal controlled oscillator." Photo-electric cell 4 receives the light from the pick-up scanner as before. In the balance circuit I have found that, since the photo-electric cell shows a variation of resistance and capacity due to temperature changes and other random effects, the use of a second photo-electric cell 14 having the same characteristics as cell 4 is advantageous as a balance means. Since it is not easy to find two cells with exactly the same resistance and capacity, condenser 13 may be added across cell 4 and resistance 12 may be added in series to give excess capacity and resistance in the circuit of cell 4. This permits the use of variable condenser 9 in parallel with cell 14 and variable resistance 8 in series to complete the balance. The variable and fixed condensers and resistors may be interchanged without departing from the spirit of the invention. Cell 14 should be connected similarly to cell 4, that is with anode 16 connected to winding 3 and cathode 15 to resistor 8. As a further balancing means, lamp 17 shining thru diaphragm 18 and focussed on cell 14 by lens 19 may be used. Varying the opening in diaphragm 18 varies the light reaching cell 14 and hence the resistance of the cell. When using the light to obtain balance one or both of resistors 12 and 8 may be eliminated. I have found that the higher the frequency of the alternating current supply, the more exact the balance required to obtain good modulation percentages due to light reaching cell 4. While the above arrangement is effective in greatly reducing the effects of temperature change on balance, it is also advantageous to reduce the temperature variations themselves. Enclosing the whole assembly of Fig. 2 exclusive of the optical systems and scanner in a temperature controlled compartment accomplishes this reduction in temperature variation. In addition resistors 8 and 12 should have as nearly as possible the same temperature coefficients as well as condensers 9 and 13.

In Fig. 3 I have shown a simplified system employing a special dual photo-electric cell. This dual photo-electric cell 20 consists of a double set of elements, one set comprising anode 21 and cathode 22 and the other anode 23 and cathode 24. The active modulating elements are anode 21 and cathode 22 with cathode 22 receiving light from the pick-up scanner or other source of light variations. Anode 23 and cathode 24 form the balance circuit and light from lamp 17 focussed by lens 19 on cathode 24 is varied by diaphragm 18 to produce balance. Cathodes 22 and 24 are connected together and to one end of variable condenser 26 and coil 25 which is also the output point. The other ends of condenser 26 and coil 25 are connected to ground G and condenser 26 is varied to tune coil 25 to resonance at the frequency of the alternating current source. This tuned circuit is useful in maintaining a high output impedance since without tuning, the capacity across the output circuit acts as a shunt. Shield plate 27 connected to ground and placed between the two sets of elements serves to keep currents from flowing between the two sets of elements.

It will be apparent to one skilled in the art

that, while I have described only a few systems whereby my invention may be carried into effect, that it is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. In a modulation system, the combination of a source of alternating current voltage, a photo-electric cell including a first cathode and an associated first anode and a second cathode and an associated second anode, means for applying a portion of the voltage from said source to one pair of said photo-electric cell elements and a tuned circuit in series and means for applying a second and out of phase voltage with respect to said above-mentioned portion from said source to the other pair of photo-electric cell elements and said tuned circuit in series.

2. In a modulating system, the combination of, a source of alternating current voltage, a photo-electric cell including a first cathode and an associated first anode and a second cathode and an associated second anode, means for applying a portion of the voltage from said source to one pair of said photo-electric cell elements and a tuned circuit in series, means for applying a second and out of phase voltage with respect to said above-mentioned portion from said source to the other pair of photo-electric cell elements and said tuned circuit in series, and including an electro-static shield interposed between said anode-cathode pairs of elements of said photo-electric cell.

3. In a modulating system, the combination of, a source of alternating current voltage, a photo-electric cell including a first cathode and an associated first anode and a second cathode and an associated second anode, means for applying a portion of the voltage from said source to one pair of said photo-electric cell elements and a tuned circuit in series, means for applying a second and out of phase voltage with respect to said above-mentioned portion from said source to the other pair of photo-electric cell elements and said tuned circuit in series, and including a source of modulated light directed upon one of said photo-electric cell anodes.

4. In a modulating system, the combination of, a source of alternating current voltage, a photo-electric cell including a first cathode and an associated first anode and a second cathode and an associated second anode, means for applying a portion of the voltage from said source to one pair of said photo-electric cell elements and a tuned circuit in series, means for applying a second and out of phase voltage with respect to said above-mentioned portion from said source to the other pair of photo-electric cell elements and said tuned circuit in series, and including a source of modulated light directed upon one of said anodes and a source of unmodulated light directed upon the other of said anodes.

5. In a modulating system, the combination of, a source of alternating current voltage, a photo-electric cell including a first cathode and an associated first anode and a second cathode and an associated second anode, means for applying a portion of the voltage from said source to one pair of said photo-electric cell elements and a tuned circuit in series, means for applying a second and out of phase voltage with respect to said above-mentioned portion from said source to the other pair of photo-electric cell elements and said tuned circuit in series, and means for maintaining the components of said system at a substantially constant temperature.

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