May 10, 1927. 1,628,377

H. VOGT ET AL

MEANS FOR CONTROLLING AMPLITUDE OF HIGH FREQUENCY OSCILLATIONS

Filed April 4, 1921 2 Sheets-Sheet 1

FIG. 1a.

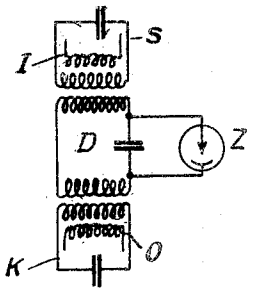
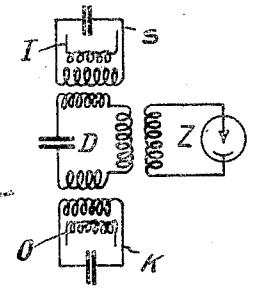
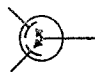


FIG. 1b.



Z. IN ALL FIGURES REPRESENTS A PHOTO-ELECTRIC CELL.

FIG. 10.



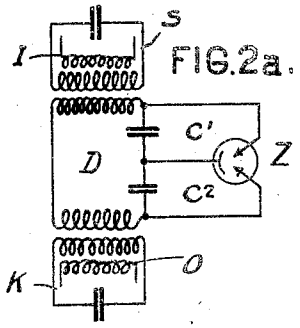


FIG. 2a.

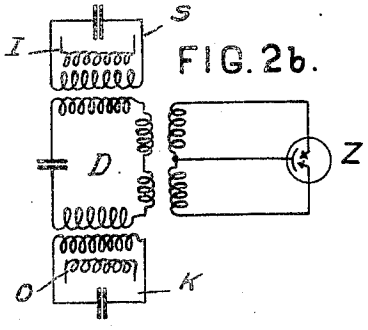


FIG. 2b.

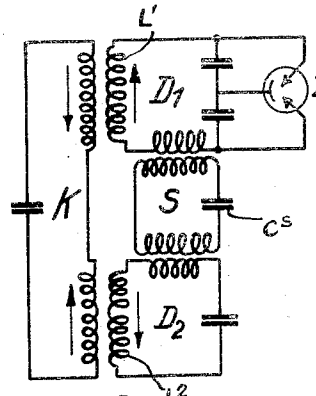


FIG. 3.

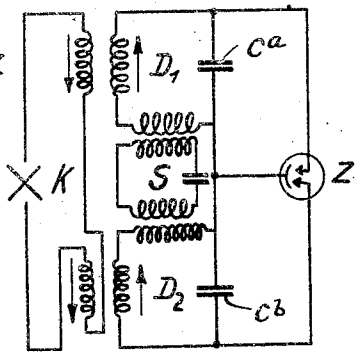


FIG. 4.

INVENTORS:
JOSEPH MASSOLLE
HANS VOGT
JOSEF ENGL
BY Munn & Co
ATTORNEYS

May 10, 1927. 1,628,377

H. VOGT ET AL

MEANS FOR CONTROLLING AMPLITUDE OF HIGH FREQUENCY OSCILLATIONS

Filed April 4, 1921 2 Sheets-Sheet 2

FIG.5a.

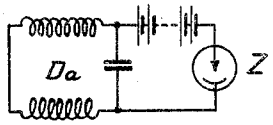


FIG.5b.

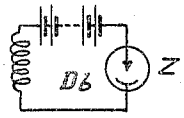
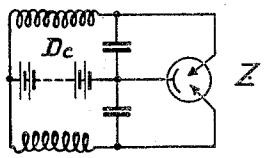


FIG.6a.



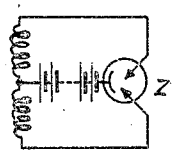


FIG.6b.

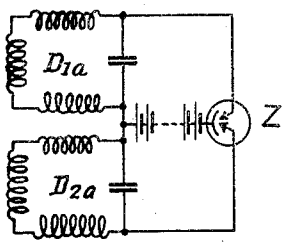


FIG.7.

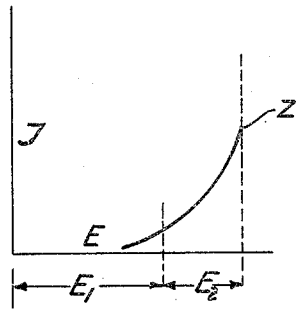


FIG.8.

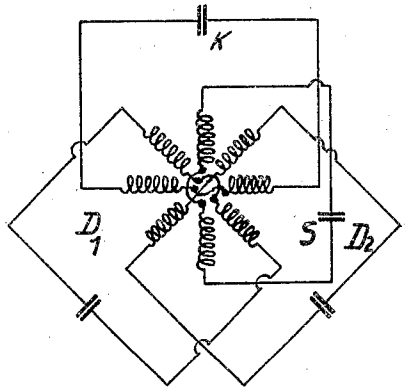


FIG. 9.

INVENTORS:
JOSEPH MASSOLLE
HANS VOGT
JOSEF ENGL
BY Munn & Co
ATTORNEYS

Patented May 10, 1927. 1,628,377

UNITED STATES PATENT OFFICE.

HANS VOGT, OF BERLIN-SCHONEBERG, AND JOSEF ENGL AND JOSEPH MASSOLLE, OF GRUNEWALD, GERMANY, ASSIGNORS TO TRI-ERGON LIMITED, OF ZURICH, SWITZERLAND.

MEANS FOR CONTROLLING AMPLITUDE OF HIGH-FREQUENCY OSCILLATIONS.

Application filed April 4, 1921, Serial No. 458,630, and in Germany April 7, 1919.

(GRANTED UNDER THE PROVISIONS OF THE ACT OF MARCH 3, 1921, 41 STAT. L., 1313.)

In order to use high frequency oscillations for purposes of transmission, recording, and reproduction low frequency oscillations, such as acoustic vibrations, their amplitude must be controlled or acted upon in the sense of the low frequency oscillations.

The present invention makes this possible in such a manner that a source of radiation controlled in the sense of the low frequency acts upon a photoelectric cell having an alkali cathode and thus controls the high frequency amplitude. The light which falls upon the photoelectric cell may be varied in intensity by and in accordance with sound vibrations, for example. Such cells, such as the potassium cell, are known. They consist of two electrodes, enclosed in a glass tube which is either at a vacuum or filled with rare gas, one of said electrodes being composed of alkaline metal. If an electrical potential is applied between these two electrodes, in such a way that the electrode which is coated with alkaline metal is negative, an irradiation of the cell by light sets up a flow of electrons from the alkaline metal to the positive electrode, this emission being directly proportional to the irradiation. If the sign of the potential be reversed, i. e. if a positive potential is connected with the alkaline metal electrodes, no flow of electrons will ensue. The resistance and the capacity between the electrodes vary according to the electron discharge.

If the cell be connected in the usual manner with an electrical oscillatory circuit the E. M. F. of which produces the requisite potential for the cell, the variations at the cell effect a control of the amplitude of the pulsating oscillations in the circuit so that the latter are directly, or almost directly, proportional to the variations in the illumination of the cell. The necessary coupling, between the cell and the oscillating circuit, may be effected directly or by induction or capacity.

In accordance with the invention a photoelectric cell is coupled to an oscillatory circuit as stated, which circuit may be one of a series of coupled, tuned circuits containing inductance and capacity, to modulate the current flowing therein in accordance with variations of illumination received by the cell. The illumination of the cell may be acoustically-modulated, as stated, or modulated, generally speaking, in accordance with some form of energy varying with a lower frequency than that of the high frequency carrier waves flowing in the said circuit or coupled circuits, so that the current flowing in said circuit or circuits will be correspondingly modulated. In a further development of the invention, oscillatory circuits, in which flow current modulated in the manner indicated, may be differentially coupled to another circuit, in which a resultant current will flow, and in which the modulation effect may be increased. Objects of the invention comprise the provision of arrangements in accordance with the foregoing, and also comprise combinations and arrangements of parts all as will be more fully set forth hereinafter in the following specification and be particularly pointed out in the appended claims.

In order that the invention may be clearly understood, we will proceed to describe the same with reference to the different forms of construction diagrammatically shown in the accompanying drawings, wherein:—

Figs. 1*a* and 1*b* show diagrams of connections between a photoelectric cell and an oscillation circuit with direct coupling and inductive coupling respectively.

Figs. 2*a* and 2*b* are views similar to Figs. 1*a* and 1*b* representing connections of a cell having three electrodes with an oscillation circuit.

Figs. 3 and 4 show different connections in which coupling of the cell can be effected indirectly.

Figs. 5*a* and 5*b*, 6*a* and 6*b* and 7 show connections to be used for producing preliminary voltage.

Fig. 8 shows a curve relating to the effect of the cell.

Fig. 9 shows a simple arrangement for coupling the circuits in a special manner.

Fig. 10 is a diagrammatic view of a photo-

electric cell having two cathodes and one anode, as a modification of the cell indicated in Figs. 2*a* and other figures.

Similar reference characters refer to similar elements or parts throughout the drawings.

In Figures 1*a* and 1*b* the circuit S in each instance is a feed circuit which, fed by a generator with undamped high frequency energy, excites the circuit D from which the energy is further transmitted to the circuit K. Circuits S, D, and K are resonant circuits, containing inductance and capacity. An input circuit is indicated at I, in circuit S, inductively coupled to circuit S, and an output circuit is similarly indicated in circuit K, at O. In the connection according to Fig. 1*a*, direct coupling is used by connecting the cell Z in parallel with the condenser of the circuit D, the maximum potential of which is adapted to that of the cell. In the connection according to Fig. 1*b*, the cell is coupled inductively to the circuit D in such a manner that the maximum potential necessary for the cell is obtained. In both cases the connection of the cell to tuned circuit D effects a slight untuning of the same, whereby the current therein, and transmitted inductively therefrom to output circuit K, is modulated in accordance with the variations of resistance in the cell, which may be produced in accordance with variations of sound-modulated light, or by other variations of radiant energy, as stated.

In these connections the cell, on account of its polarity, becomes operative only during each half period of the oscillations in circuit D. Bilateral action takes place by the connections as shown by Figs. 2*a* and 2*b* in which a cell is provided with three electrodes of which two are of the same polarity (say, positive), one of which becomes operative during each half-period.

In Fig. 2*a* the cell has two anodes, each connected to circuit D across a capacity, condensers C^1 and C^2 being positioned in circuit D between the connections from the cathode of the cell and one anode, and between the connections from the cathode and the other anode, respectively. Current flows from one anode during one half of the cycle of the alternating current, and from the other anode during the other half. Circuit D is slightly untuned by the varying charging of the condensers, so that both halves of the cycle are utilized and the modulated current flows in circuit D during the complete cycle. Fig. 2*b* is the same except that the cell circuits are inductively coupled to circuit D. Fig. 10 shows a modified form of cell in which a single anode is used with a pair of cathodes, instead of a single cathode and a pair of anodes, as in Fig. 2*a*. This cell may be substituted for the cell shown in Figs. 2*a*, 2*b*, 3 and 4, and suitable connections made therefrom to the oscillatory circuit or circuits.

The effects produced in the circuit D by the variations of resistance of the cell are in the case of each coupling method as follows, viz:

1.—Variation of the damping and

2.—Variation of the wave.

Because of varying the illumination of the photo-electric cell, the ohmic resistance of the cell is altered. Hence, the circuit D is untuned with respect to the frequency of circuit S. The damping loss of circuit D is also varied by altering the ohmic resistance of the photo-electric cell. Both facts, namely untuning and variation of damping, cause variation in the transfer of high frequency energy from circuit S through circuit D to circuit K. By a proper choice of the original damping of circuit D both facts may be utilized either together or one more than the other.

The amplitude variation caused by the variation of frequency will not be great with the connection arranged as shown in Figs. 2*a* and 2*b*. It can be greatly increased by differential connections in which the phase displacement between the current and voltage, caused by somewhat untuning the oscillating circuit, is made use of.

Figs. 3 and 4 show such differential connections in which the coupling of the cell can also be effected indirectly. In both figures, there are provided two circuits D^1 and D^2 which are excited by circuit S and which transmit the energy to circuit K. All the circuits are tuned to the same wave and so intercoupled that with a non-illuminated cell no current flows through the circuit K. In the connection shown in Fig. 3 the circuit D^1, with the cell exposed to light, is altered in the same way as the circuit D in the connections shown by Fig. 2*a*, circuit D^2 remaining unaltered. The difference of its amplitudes as compared with those of D^1 is now transmitted to the circuit K in which, as the variation of the amplitudes of D^1 occur at each half period, an alternating current of the same frequency is generated.

In the connections shown in Fig. 3 the inductances L^1 and L^2 in circuits D^1 and D^2, affecting circuit K, are wound in the same direction. The feed circuit S has inductances on opposite sides of the condenser C^5 in circuit S, and accordingly feeds circuits D^1 and D^2 oppositely. Accordingly, L^1 and L^2 being wound in the same direction, circuits D^1 and D^2 induce current in opposite directions in circuit K, and the resulting current in circuit K is zero when the cell is not illuminated. When the cell Z is illuminated, circuit D^1 is slightly untuned thereby, which results in a differential effect in circuit K, so that a modulated high frequency current flows in circuit K, which is

a resultant of the effects produced by circuit D^2 and the slightly untuned circuit D^1.

The current flowing in circuit K varies between two limits, the upper limit being the current induced by circuit D^2 alone, when no current is induced by circuit D^1, because the latter has been untuned to a sufficient extent. At the other limit circuit D^1 exerts a certain inductive effect on circuit K, which counteracts to this extent the effect of circuit D^2 on K. The action of the differential circuits is somewhat similar to that described in our co-pending application, Serial No. 457,137, filed March 30, 1921, differential connection for electrical frequencies.

With the differential connection shown by Fig. 4 the effects are alternately produced in D^1 and D^2. As both circuits in their effect on K are displaced by a phase angle of 180°, the current transmitted to K has always the same direction. It is therefore a pulsating continuous current with the rhythm of the high frequency half-period, which can eventually be used directly.

The connections in Fig. 4 differ from those of Fig. 3 in that the differential circuits D^1 and D^2 are connected, one to one anode and the other to the other anode of cell Z, the cathode of which is connected to circuits D^1 and D^2 between the condensers C^a and C^b thereof, the anodes of the cell being connected on the opposite sides of the condensers. Accordingly, untuning effects are obtained in circuits D^1 and D^2, in one in one half of the cycle, and in the other in the other half of the cycle. The inductive couplings of circuits D^1 and D^2 with circuit K are so wound as to produce opposite effects and input circuit S being oppositely connected by inductance to circuits D^1 and D^2, the result is that an undulating direct current is produced in circuit K, the connections described rectifying the current.

For the rest, the current produced in all the various connection schemes can be amplified whereby those produced according to Fig. 4 again become alternating currents, but of double the frequency of those of the circuit D.

In case of amplification, the differential connections as shown by Figs. 3 and 4 have the advantage over the simple arrangements shown by Figs. 1*a* and 2*a* that the current to be amplified pulsates from zero up to a maximum which permits a better utilization of the amplifier device.

The effect of the cell sensitive to irradiation is not proportional to the voltage applied. It starts practically only at a certain definite voltage and then rises in a steep curve until at a given voltage, glow discharge sets in (Fig. 8). The controlling effect of the cell in conjunction with an oscillatory circuit is thereby considerably diminished as the phase is only intensively utilized from a fairly high tension onwards. By means of a suitably selected direct current preliminary voltage this can be avoided. The alternating voltage E^2, which practically can attain to the flashing point Z, comes thereby within the range of the steep curve. In the Figs. 5*a*, 5*b*, 6*a*, 6*b* and 7 possible connections for providing the preliminary voltage are shown.

Figs. 5*a*, 5*b*, 6*a* and 6*b* correspond respectively to Figs. 1*a*, 1*b*, 2*a* and 2*b*, with circuits D*a*, D*b* and D*c* of Figs. 5*a*, 5*b* and 6*a* corresponding to the circuits D of Figs. 1*a*, 1*b*, and 2*a*. To make Figs. 5*a*, 5*b* and 6*a* complete, the circuits S and K, as shown in Figs. 1*a*, 1*b* and 2*a*, should be added. They will then differ from circuits 1*a*, 1*b* and 2*a* only in that the direct current source is included in circuit with cell Z in each case. Fig. 6*b* may be made complete by the addition of circuits S, D and K, as shown in Fig. 2*b*. Fig. 7 corresponds to Fig. 4, with the inclusion of the direct current source in circuit with the cell, and may be completed by the addition of circuits S and K of Fig. 4. In all of them the current output of the cell is improved as shown by the current-voltage characteristic of the cell shown in Fig. 8, in which E_1 is the constant direct voltage and E_2 is the alternating current voltage transmitted to circuit D*a*, D*b*, D*c*, etc. The current in Fig. 8 is represented by the vertical co-ordinate.

In order to obtain the most favourable conditions with the differential connections the circuit K must not be directly coupled with circuit S. S must supply its energy only to D_1 and to D_2 which whenever possible must also have no coupling with each other, and with which K is so coupled that the currents in D_1 and D_2 compensate each other so long as the cell is not irradiated. Only when by the irradiation of the cell the balance or static condition between D^1 and D^2 is disturbed, the measure of this disturbance is transmitted to K. A simple arrangement for producing these conditions of coupling is that shown by Fig. 9 in which the requisite four coils are arranged in one field. D^1 and D^2 are perpendicular to one one another, as are also S and K. S and K are then so turned with regard to D^1 and D^2 that in K the desired effect is produced.

That is to say, there will be no material inductance effects between S and K, and between D^1 and D^2, but coupling between the coils which are at angles of 45° from each other will exist, so that circuit S will induce currents in circuits D^1 and D^2, and circuits D^1 and D^2 will induce currents in circuit K, as explained in connection with Figs. 3 and 4.

It will be noted that, as to any features of this application and our co-pending ap-

plication Serial No. 457,137 referred to above, which may be common to both, in regard to differential circuits, claims covering such common subject matter will be made in our said co-pending application.

We claim:—

1. In electric-oscillation controlling devices, the combination of a tuned high-frequency oscillatory circuit, containing inductance and capacity constituting the tuning factors of said circuit, means for setting up high frequency oscillations in said circuit, a photoelectric cell and means for coupling said cell to said circuit by one of said tuning factors to vary the inductance-capacity product thereof and thereby somewhat untune the same in accordance with variations of light received by said cell.

2. In electric-oscillation controlling devices, the combination of a plurality of tuned circuits, containing capacity and inductance, coupled together, means for supplying high frequency oscillations to one of said circuits, a photoelectric cell, and means for coupling said cell to another one of said circuits to vary the inductance-capacity product thereof, to somewhat untune the same and thereby cause modulation of the current in said circuit in accordance with variations of light received by said cell.

3. In electric-oscillation controlling devices, the combination of a tuned high frequency oscillatory circuit containing inductance and capacity, means for setting up high frequency oscillations in said circuit, a photoelectric cell having an anode and a cathode, and means for so coupling said cell to said circuit as to provide from the E. M. F. of said circuit, a difference of potential between the electrodes of said cell, with the cathode negative with respect to the anode to vary the inductance-capacity product of said circuit, to somewhat untune the same, and thereby cause modulation of the current in said circuit in accordance with variations of light received by said cell.

4. In electric-oscillation controlling devices, the combination of a high frequency oscillatory circuit containing inductance and capacity, means for setting up high frequency oscillations in said circuit, a photoelectric cell having an anode and a cathode, and means for connecting said anode and cathode across capacity in said circuit to vary the inductance-capacity product of said circuit, to somewhat untune the same, and thereby cause modulation of the current in said circuit in accordance with variations of light received by said cell.

5. In electric-oscillation controlling devices, the combination of a tuned high frequency oscillatory circuit containing inductance and capacity, means for setting up high frequency oscillations in said circuit, a photoelectric cell having one electrode of one polarity and two electrodes of opposite polarity, the inductance and capacity of said circuit constituting the tuning factors thereof, and means for so coupling said electrodes by one of said tuning factors to said circuit as to vary the inductance-capacity product of said circuit, to somewhat untune the same, and thereby cause modulation of the current in said circuit during the whole cycle of the high frequency alternating current in accordance with variations of light received by said cell.

6. In electric-oscillation controlling devices, the combination of a resonant high frequency oscillatory circuit containing inductane and a pair of condensers, means for setting up oscillations in said circuit, a photoelectric cell having a cathode and a pair of anodes, and means for connecting the cathode and one anode across one of said condensers and the cathode and the other anode across the other one of said condensers to cause modulation of the current in said circuit in accordance with variations of light received by said cell.

7. In electric-oscillation controlling dedevices, the combination of a pair of circuits, containing similar inductance and capacity, means for supplying alternating current equally thereto, the capacity-inductance products of said circuits being so adjusted that currents flowing therein will have a desired normal phase relation to each other, a third circuit so coupled with said first two circuits as to have a resultant current produced therein, a photoelectric cell, and means for coupling said cell to one of said first two circuits to slightly untune said circuit in accordance with variations of light received by said cell, to correspondingly alter the differential effect of said first two circuits on said third circuit.

8. In electric-oscillation controlling devices, the combination of a pair of circuits, containing similar inductance and capacity, means for supplying alternating current equally thereto, the capacity-inductance products of said circuits being so adjusted that currents flowing therein will have a desired normal phase relation to each other, a third circuit so coupled with said first two circuits as to have a resultant current produced therein, a photoeletric cell, having a cathode and a pair of anodes, the inductance and capacity of said first two circuits constituting the tuning factors thereof, and means for so coupling the electrodes of said cell to said first two circuits, by one of the tuning factors of each, as to cause modulation of the current flowing in one of said first two circuits during one half of the cycle of the alternating current, and modulation of the current flowing in the other of said first two circuits, during the other half of the cycle, to modify correspondingly the

current produced in said third circuit, in accordance with variations of light received by said cell.

9. In electric-oscillation controlling devices, the combination of a feed circuit, a pair of circuits coupled therewith to be supplied equally with alternating current thereby, all of said circuits containing similar inductance and capacity, a fourth circuit differentially coupled to said pair of circuits to receive a resultant current therefrom, and means for variably untuning one of said pair of circuits to correspondingly alter the current produced in said fourth circuit, the inductance coils of said feed and fourth circuits being at right angles and the inductance coils of said pair of circuits being at right angles to each other.

In testimony whereof we affix our signatures.

HANS VOGT.
DR. JOSEF ENGL.
JOSEPH MASSOLLE.