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R. V. L. HARTLEY

1,472,470

METHOD OF AND MEANS FOR PRODUCING ALTERNATING CURRENTS

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Fig. 1.

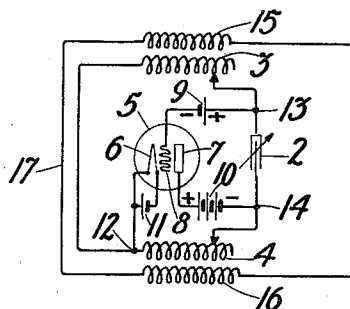


Fig. 2.

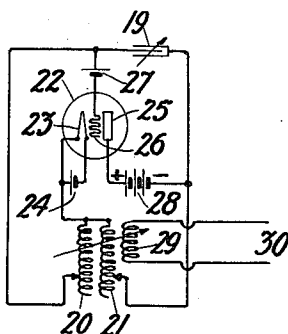
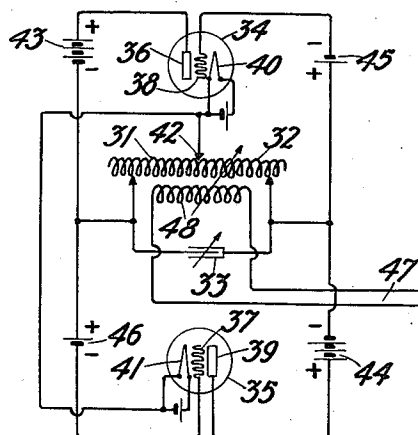


Fig. 3.



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UNITED STATES PATENT OFFICE.

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METHOD OF AND MEANS FOR PRODUCING ALTERNATING CURRENTS.

Application filed March 30, 1918. Serial No. 225,808.

To all whom it may concern:

Be it known that I, RALPH V. L. HARTLEY, a citizen of the United States, residing at Brooklyn, in the county of Kings, State of New York, have invented certain new and useful Improvements in Methods of and Means for Producing Alternating Currents, of which the following is a full, clear, concise, and exact description.

This invention relates to methods of and means for producing alternating currents in which an oscillatory circuit is associated with means for supplying increments of electrical energy thereto in definite timed relation with respect to the oscillations existing in the circuit.

More particularly, this invention relates to an oscillation generator in which increments of energy are supplied from a source of electrical energy to an oscillating circuit through a discharge device, the impedance of which is periodically varied by oscillations in the oscillating circuit.

An object of the invention is to provide a method and means for producing an alternating current of readily controllable frequency.

Another object of the invention is to provide a source of alternating current of substantially pure sinusoidal wave form.

A further object of the invention is to provide an oscillator having a frequency determining oscillation circuit, two elements of which are so related electrically that the one serves to cause energy of the oscillation circuit to be fed back to that circuit through the other element.

A still further object of the invention is to provide a balanced oscillator of the vacuum tube discharge type in which the limiting effect upon the amplitude of the oscillations will be the same during both positive and negative portions of the cycle.

An additional object of the invention is to provide means for producing oscillations of radio frequency.

If the input and output circuits of an amplifying device or repeater are so related electrically that any change in the output circuit affects the input circuit in such a manner as to produce a still greater change in the same direction, the change builds up until checked by the development of some opposing force in the system, as for exam-

ple, that of the rising electromotive force of a charging condenser. After this, there is a tendency for a change to take place in the opposite direction and this change builds up until checked by some opposing force. This oscillating process takes place at a frequency determined by the electrical inertia and stiffness of the system, that is, its inductance and capacity.

If oscillations of a readily controllable frequency are to be set up, a resonant circuit may be associated with the amplifier in such manner as to govern the frequency of the alternating changes. It has been discovered that by properly relating the input and output circuits of the repeating or amplifying device to the resonant circuit, oscillations of substantially pure sine wave form and of readily controllable frequency may be produced. Oscillations of low frequency or of high frequency may thus be produced according to the natural period given the resonant circuit.

In the drawing, Fig. 1 illustrates diagrammatically one form of a vacuum tube type oscillation generator; Fig. 2 illustrates a modification; and Fig. 3, a still further modification.

Referring to Fig. 1, variable capacity 2, and variable inductances 3 and 4 constitute a closed oscillation circuit the natural period of which may be varied as desired. A vacuum tube discharge device comprising a highly evacuated container 5, includes a hot cathode 6, a plate electrode 7 and an impedance varying member 8. Elements 7 and 8 are connected to terminals 14 and 13 respectively of capacity 2 through sources of electrical energy 10 and 9. Source 9 serves to maintain grid 8 at a potential which is always negative with respect to cathode 6. Source 10 acts to supply space current between electrodes 6 and 7 to which its negative and positive terminals are respectively connected. Cathode 6 is heated by a source of electrical energy 11 and is connected to a point 12 between inductances 3 and 4.

A circuit or line 17 is linked with both inductances 3 and 4 by means of coupling coils 15 and 16 respectively. Vacuum tube 5 with its associated circuits as described, is identical with one form of the oscillation generator disclosed in Patent No. 1,356,763

of October 26, 1920, R. V. L. Hartley, in which patent the present invention is claimed broadly, and a second modification is claimed specifically. The present appli-
 5 cation is a continuation of application, Serial No. 31,476, filed June 1, 1915, which matured into the above patent, as to this matter.

The underlying principles of the operation of this invention have been previously outlined. Variations in the current passing through inductance 4 of the output circuit between electrodes 6 and 7 cause variations to be set up in circuit 17 through the coupling between inductances 4 and 16. Variations
 10 set up in circuit 17 are reimpressed by coil 15 of circuit 17 upon the coupled inductance 3 in the input circuit between cathode 6 and grid 8. These variations in the input circuit produce corresponding changes in the output current and so the process continues. In this manner, oscillations having a period determined by the values of inductances 3 and 4 and capacity 2 of the oscillation circuit are generated and may be supplied by
 15 circuit or line 17 to a load or work circuit.

Fig. 2 illustrates a somewhat modified form of oscillation generator. An oscillatory circuit comprises variable capacity 19 and two-part inductance 20, 21, the parts of which are variably coupled to each other. A highly evacuated container 22 has a cathode 23 heated to incandescence by an external source 24 of electrical energy, a plate electrode 25 and a grid 26. Grid 26 is connected to one terminal of condenser 19 through a source 27 which serves to keep the grid at a proper potential with respect to the cathode, and plate electrode 25 is connected to the opposite terminal of condenser 19 through a source 28 of space current. Cathode 23 is connected to an intermediate point of the two-part inductance 20, 21. Variably coupled to the inductances 20 and 21 is a coil 29 of a transmission conductor or work circuit 30 to which the oscillation energy may be supplied.

The operation of this type of generator is substantially the same as that of the oscillator illustrated in Fig. 1, except that inductance 21 in the output or filament plate circuit of the vacuum tube device 22 feeds back energy directly to the input or filament grid circuit through coupled inductance 20. The closed oscillation circuit in both forms of generator described includes a portion of the output circuit and a portion of the input circuit of a vacuum tube which are so related that energy is fed back from the output to the input.

Fig. 3 illustrates a form of oscillator employing two vacuum tubes. A closed oscillation circuit comprising two-part variable inductance 31, 32 and a variable capacity 33 is associated with two highly evacuated con-

tainers or tubes 34 and 35 having a plate electrode 36 of tube 34 and a grid element 37 of tube 35 connected to one terminal of capacity 33 and a grid element 38 of tube 34 and a plate electrode 39 of tube 35 connected to the opposite terminal of capacity 33. Cathodes 40 and 41 of tubes 34 and 35 respectively are connected to a common tap 42 which has a variable point of connection to two-part inductance 31, 32. Sources 43 and 44 of electrical energy supply space current in the output circuits of tubes 34 and 35 respectively and sources 45 and 46 maintain the grid elements of their respective tubes at the proper normal potentials with respect to the cathodes.

A line or work circuit 47 includes a coil 48 variably coupled to two-part inductance 31, 32. As in the case of the circuit 17, illustrated in Fig. 1, this line has an effect in coupling the two inductances 31 and 32 to each other so as to feed back energy from the one to the other, but this effect is not essential to the operation of the device and the coupling with coil 48 may be made very loose, since the end to end coupling between the two parts of the inductance 31, 32 is sufficient to give the necessary feed back.

It will be apparent that when the oscillating current in the oscillation circuit 31, 32, 33 is in such direction as to tend to charge grid 37 positively, it will tend to charge grid 38 negatively and vice versa. A consequent decrease in the internal impedance of tubes 34 and 35 occurs alternately, and corresponding surges of space current pass alternately through their respective space current or output circuits. Accordingly one space current source is drawn upon during one-half cycle and the other space current source during the other half cycle. This enables a more symmetrical wave form to be secured under all conditions of load, since if the tubes and their associated circuits and sources of energy are substantially alike, the limiting effect of each tube, upon the amplitude of its own space current during overload of the generator, is the same. If but a single tube were used, the limiting effect at overloads would result in dissymmetry since the alternate half cycles would be of less amplitude. In other respects the operation of this form of oscillator is the same as that of the forms previously described.

While three specific forms of oscillation generators have been illustrated and described it is to be understood that this invention is not to be limited to the specific circuit arrangements disclosed, but includes all such modifications as fall within the scope of the appended claims.

What is claimed is:

1. An oscillator comprising a closed oscillation circuit, a vacuum tube discharge device having an input circuit including one

portion of said oscillation circuit and an output circuit including a second portion of said oscillation circuit inductively coupled to said first mentioned portion, said oscillation circuit determining the frequency of the oscillations produced by said oscillator.

2. Means for generating oscillations and transmitting them to a work circuit comprising a discharge device having a cathode, an anode and an impedance varying element, an oscillatory circuit including a capacity element, leads from said anode, and said impedance varying element to the opposite terminals of said capacity element respectively and oscillation paths comprising inductive means for transferring energy from one path to the other, connecting said cathode to said anode and to said impedance varying element respectively.

3. An oscillator comprising an oscillation circuit, a vacuum tube having an input element and an output electrode connected to electrically remote points in said oscillation circuit, a cathode connected to an intermediate point in said oscillation circuit, the portions of said oscillation circuit adjacent to said cathode connection being inductively coupled and said oscillation circuit determining the frequency of the oscillations produced by said oscillator.

4. An oscillator comprising a vacuum tube having input and output circuits including inductances inductively coupled to each other and a condenser connecting the electrically remote terminals of said inductances to form with such inductances a closed oscillation circuit, said oscillation circuit determining the frequency of the oscillations produced by said oscillator.

5. A generator of oscillations of a given frequency comprising a closed oscillation circuit tuned to the given frequency, a vacuum tube having a cathode, an anode, and an impedance varying element, each connected to an electrically different point in said oscillation circuit, the portions of said oscillation circuit immediately adjacent to the point of connection to the cathode being inductively coupled.

6. An oscillation generator comprising a vacuum tube having a cathode, a grid element and an output electrode, an input circuit including an inductance connected to said grid element and said cathode, an output circuit including an inductance inductively coupled to said first-mentioned inductance, connected to said output electrode and said cathode, and an oscillation circuit including at least a portion of each of said inductances, said oscillation circuit determining the frequency of the oscillations produced by the oscillation generator.

7. Means for generating oscillations and transmitting them to a work circuit com-

prising an inductance, a discharge device having an anode, a cathode, and an impedance varying element, a lead from said cathode to a point in said inductance, a lead from said anode to said inductance, a lead from said impedance varying element to said inductance, an electrical capacity in shunt to at least a portion of said inductance, including at least a portion of that part of said inductance which lies between the leads from said cathode and said anode, the parts of said inductances adjacent to the lead from said cathode being electrically related so as to feed back energy from the one part to the other.

8. The combination with an oscillatory circuit comprising a two-part inductance and a condenser in series, of a thermionic repeater having a cathode, an anode and a control electrode, a connection including a primary source of electromotive force between said anode and one terminal of said condenser, and a connection including another primary source of electromotive force between said control electrode and the other terminal of said condenser, the two parts of said inductance being arranged to transfer energy inductively from the one to the other.

9. An oscillator comprising a vacuum tube device having input and output circuits each including elements of the same oscillatory circuit, and means for transmitting oscillations inductively coupled to said elements.

10. An oscillator comprising a single vacuum tube device having input and output circuits each including elements of the same oscillatory circuit, and a circuit inductively coupled to said elements.

11. In an oscillator, an oscillation circuit comprising a capacity element, a vacuum tube discharge device having an anode connected to one terminal and a grid element connected to the opposite terminal of said capacity element, a cathode connected with a third point of said oscillation circuit, and a transmission circuit inductively related to the portions of said oscillation circuit adjacent said third point.

12. In an oscillator, two inductively coupled inductances, a capacity element associated with said inductances to form a tuned circuit, and a single vacuum tube discharge device having a cathode, an anode and an impedance control element connected to electrically remote points in said oscillation circuit.

13. In an oscillator, an oscillatory circuit comprising a capacity element, and a two-part inductance, the parts of said inductances being directly coupled to each other, and a three element discharge device having a cathode connected to a point intermediate the parts of said inductance and an anode and an impedance control element each con-

nected to a terminal of said capacity element.

14. A vacuum tube discharge repeater having an input circuit and an output circuit, each said circuit containing an inductance element, said elements inductively coupling said circuits and a capacity element also coupling said circuits, said inductance and capacity elements being in series with each other and constituting a closed oscillatory circuit, the natural frequency of which substantially determines the frequency of the oscillations repeated.

15. A vacuum tube oscillator comprising an oscillatory circuit and a repeater having a cathode, an anode and a control element each connected to an electrically different point in said oscillation circuit, the connections of said anode and said control element to said oscillatory circuit including sources of unidirectional electromotive force oppositely poled with respect to said cathode.

16. An oscillator comprising a closed tuned circuit including capacity and inductance, an amplifier having a cathode, an anode and a control element each connected to electrically distinct points in said oscillatory circuit, and a transmission circuit coupled to part at least of the inductance of the oscillatory circuit.

17. Means for generating oscillations comprising a discharge device having a cathode, an anode, and an impedance controlling element, inductively coupled input and output circuits, one of said circuits including a tuned loop, and leads connecting said cathode and impedance controlling element to electrically remote points in said tuned loop, the reactance of said leads being negligible in determining the period of the oscillations generated.

18. An oscillation generator comprising an electric discharge device having a cathode, an anode, and an impedance control element, an oscillatory circuit, a lead connecting the impedance control element to a point in said oscillatory circuit, the reactance of said lead being negligible in determining the frequency of the generated oscillations, means connecting said cathode and anode to said oscillatory circuit at points electrically remote from said first mentioned point, said oscillatory circuit and said connecting means comprising inductively coupled oscillation paths extending between the cathode and said anode and control element, respectively.

19. An oscillation generator comprising an electron discharge device having a cathode, an anode and an impedance control element, input and output circuits therefor, each said circuit containing an inductance element, said elements inductively coupling said circuits and constituting a portion of the same closed oscillatory circuit, the nat-

ural frequency of which determines the frequency of the oscillations generated, and means normally maintaining the control element at a fixed average potential negative with respect to the cathode.

20. An oscillation generator comprising an electron discharge device having an anode, a cathode and an impedance controlling element, an input and an output circuit for said device, an oscillatory circuit associated with said device for determining the frequency of oscillations generated, means connecting said impedance controlling element to said oscillatory circuit, and means for maintaining said impedance controlling element at an average potential negative with respect to said cathode, the reactance of said connecting means being negligible in determining the frequency of oscillations generated and said input and output circuits being inductively connected.

21. An oscillation generator comprising an electron discharge device having a cathode, an anode and an impedance controlling element, input and output circuits for said device, an oscillatory circuit, leads conductively connecting said oscillatory circuit with said cathode and impedance controlling element, means inductively associating said input and output circuits, and means for maintaining said impedance controlling element at an average potential negative with respect to said cathode, the reactance of said leads being negligible in determining the frequency of the oscillations generated.

22. An oscillation generator comprising an electron discharge device having a cathode, an anode and an impedance control element, input and output circuits therefor, each said circuit containing an inductance element, said elements inductively coupling said circuits and constituting a portion of the same closed oscillatory circuit, the natural frequency of which determines the frequency of the oscillations generated, and a source of direct current normally maintaining the control element at a fixed average potential negative with respect to the cathode.

23. An oscillation generator comprising an electron discharge device having an anode, a cathode and an impedance controlling element, an input and an output circuit for said device, an oscillatory circuit associated with said device for determining the frequency of oscillations generated, means connecting said impedance controlling element to said oscillatory circuit, and a source of direct current for maintaining said impedance controlling element at an average potential negative with respect to said cathode, the reactance of said connecting means being negligible in deter-

mining the frequency of oscillations generated and said input and output circuits being inductively connected.

24. An oscillation generator comprising
5 an electron discharge device having a cathode, an anode and an impedance controlling element, input and output circuits for said device, an oscillatory circuit, leads
10 conductively connecting said oscillatory circuit with said cathode and impedance controlling element, means inductively associating said input and output circuits, and a source of direct current for maintaining
15 said impedance controlling element at an average potential negative with respect to said cathode, the reactance of said leads being negligible in determining the frequency of the oscillations generated.

25. An oscillation generator comprising
20 an electric discharge device having a cathode, an anode and an impedance control element, input and output circuits therefor, each said circuit containing an inductance element, said elements inductively coupling said circuits and constituting a portion
25 of the same closed oscillatory circuit, the natural frequency of which determines the frequency of the oscillations generated, and means normally maintaining the control element at a fixed average potential at
30 least as negative as any point of said cathode.

26. An oscillation generator comprising

an electron discharge device having an anode, a cathode and an impedance controlling element, an input and an output circuit
35 for said device, an oscillatory circuit associated with said device for determining the frequency of oscillations generated, means connecting said impedance controlling element to said oscillatory circuit, and means
40 for maintaining said impedance controlling element at an average potential at least as negative as any point of said cathode, the reactance of said connecting means being
45 negligible in determining the frequency of oscillations generated and said input and output circuits being inductively connected.

27. An oscillation generator comprising
50 an electron discharge device having a cathode, an anode and an impedance controlling element, input and output circuits for said device, an oscillatory circuit, leads
55 conductively connecting said oscillatory circuit with said cathode and said impedance controlling element, means inductively associating said input and output circuits, and means for maintaining said impedance
60 controlling element at an average potential at least as negative as that of any point of said cathode, the reactance of said leads being negligible in determining the frequency of the oscillations generated.

In witness whereof, I hereunto subscribe my name this 26th day of March, A. D. 1918.

RALPH V. L. HARTLEY.