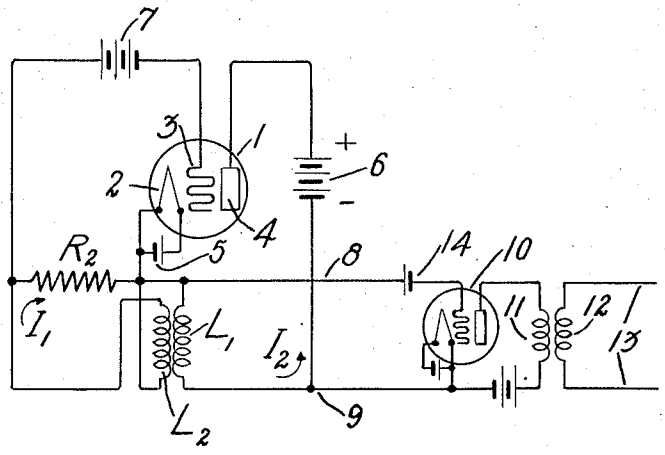
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MEANS FOR PRODUCING ELECTRICAL OSCILLATIONS

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MEANS FOR PRODUCING ELECTRICAL OSCILLATIONS.

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To all whom it may concern:

Be it known that I, HAROLD W. NICHOLS, a citizen of the United States, residing at Maplewood, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Means for Producing Electrical Oscillations, of which the following is a full, clear, concise, and exact description.

This invention relates to means for producing electrical oscillations. More particularly, it relates to the means for controlling the frequency of the oscillations produced by generators of the feed-back or reaction amplifier type.

The object of the invention is to provide an oscillator having non-resonant means for determining the frequency of the oscillations generated.

It is well known that if the output circuit of an amplifier be connected with the input circuit of the same amplifier, or if means be provided for feeding back energy from the output to the input circuit, oscillations will result if certain necessary conditions are present. Ordinarily, an electric discharge amplifier having its output circuit reactively coupled to its input circuit is used, and the frequency of the oscillations generated is determined by the tuning of a circuit which may comprise parts of either the input circuit, the output circuit, or both. Where a tuned circuit is not provided, the oscillations will have a frequency depending upon the capacity of the tube itself and the associated capacities and inductances.

According to the present invention, the output circuit of an amplifier, preferably a thermionic device, is arranged to feed back energy to its input circuit, the output and input circuits both having only one kind of reactance. There is accordingly no resonant or oscillatory circuit, and the frequency of the oscillations is determined by the value of the various constants of the circuit and the amplifying tube, as will hereinafter appear. Such a device may be termed a non-resonant oscillator.

In the accompanying drawing—1 represents the container, preferably highly exhausted, having the usual hot cathode 2, impedance-controlling element 3 and anode 4. A source 5 may supply heating current to filamentary cathode 2. The space current or output circuit comprises cathode 2, inductance L_1 constituting the primary of a transformer, space current source 6 and anode 4. The input circuit comprises cathode 2, inductance L_2 which is inductively coupled to inductance L_1, polarizing source 7 and impedance-controlling element 3. Polarizing source 7 is not essential and may be omitted. A resistance R_2 is connected in shunt to inductance L_2 of the input circuit. An asymmetrically conducting amplifier 10, preferably of the thermionic type, has an input circuit connected by leads 8 and 9 across the terminals of output inductance L_1. The output circuit of amplifier 10 includes the primary winding 11 of a transformer, the secondary winding 12 of which is connected to transmission conductor or work circuit 13. The input circuit of amplifier 10 may contain a polarizing source 14.

The physical process occurring is as follows:

Suppose the space current circuit 2, L_1, 6, 4 is suddenly closed. The current in this circuit will at first increase rapidly and an electromotive force will be induced by L_1 in winding L_2, thus bringing the impedance-control element 3 to a more positive potential with respect to the cathode 2. This causes further increase in the space current and consequent increase in the potential of the control element, these increases, however, being at a slower rate as the space current approaches its limiting value, as determined by the impedance characteristic of the thermionic amplifier. Finally, a point is reached at which the rate of space current increase is so small that the electromotive force induced in the input circuit is less than before and the potential of the controlling element or grid accordingly begins to fall. Falling grid potential causes the space current to begin to decrease and the decrease of space current in coil L_1 is accompanied by an induced electromotive force in coil L_2 tending to make the grid still more negative. In this manner the space current decreases to a minimum value, when it finally is caused to increase again by a reversal in the changes of grid potential. These reversals in the action of the impedance-control element continue indefinitely if the various constants of the network including the tube and its associated circuits are properly chosen, The space current, through inductance L_1, accordingly rises and falls cyclically in value.

Any suitable means may be used for transferring to a work circuit the alternating component of the space current energy.

As illustrated in the drawing, the input circuit of an asymmetric thermionic amplifier 10 is connected directly across the inductance L_1, and the output circuit of amplifier 10 will therefore supply amplified oscillations to work circuit 13 by means of transformer 11, 12. The polarizing source 14 may be used to prevent leak current in the input circuit of amplifier 10. The amplifier 10 is a potential-operated device and acts as an infinite resistance and infinitesimal capacity in shunt to the winding L_1. The frequency of the oscillator is independent of any oscillatory circuits or of electrical "tuning" as it is commonly understood. Such an oscillator is therefore entirely different in the matter of its frequency control from those in which both the stiffness and inertia factors determine the generated frequency.

Viewed broadly, the input and output circuits are typical of any energy transfer system in which the capacity or potential energy storage factor is negligible, and the amplifier acts as a valve under the control of said system to permit the periodic transfer of energy from a primary source of energy, such as source 6, to said system. Potential energy storage factor is a general term used to designate the capacity of a system, whether such capacity is due to the physical relation of the elements of the system, such as the wiring between individual pieces of apparatus, or due to a condenser as conventionally understood.

It is not essential that the amplifier be a vacuum tube device since any asymmetric mutual impedance arrangement may be used. By asymmetric mutual impedance is meant an impedance in which the input and output circuits or elements have such mutual relationship that the impedance of one is directly dependent upon some characteristic of the other, the impedance of the other being substantially independent of the conditions or characteristics of the one which it controls. Such an impedance may of course comprise dynamical as well as purely electrical elements.

The general conditions under which oscillations may be produced in this manner may be shown as follows:

Suppose that by means of polarizing source 7, or otherwise, substantial flow of leak current in the internal path of the tube input circuit is prevented. The input electromotive force v will be equal to that across R_2 or—

$$(1) \quad v = R_2 I_1$$

where I_1 is the instantaneous current in the mesh R_2L_2. The potential v of the impedance-controlling member with respect to the cathode may be considered as producing a corresponding variation V in the effective output electromotive force which will be equal to the potential v multiplied by the amplifying constant μ of the amplifier giving—

$$(2) \quad V = \mu v.$$

From (1) and (2) it follows—

$$(3) \quad V = \mu R_2 I_1.$$

The differential equation or characteristic for the above circuit may be written as follows:

$$(4) \quad L_1 p I_2 + R_1 I_2 - mp I_1 = -V = -\mu R_2 I_1$$

where

$$p = \frac{d}{dt}$$

the differential operator, I_2 represents the instantaneous value of space current, R_1 the internal impedance of the tube between the space current electrodes 2 and 4 and m the mutual inductance between L_1 and L_2. The quantity V is negative in the second member of the equation for the reason that a variation of potential in the input circuit is attended with a corresponding output variation electromotive force of the opposite sign. In other words, as the potential of the cathode 2 with respect to impedance-control element 3 is increased, the effective potential of cathode 2 with respect to anode 4 is proportionally decreased.

The differential equation for the closed branch R_2L_2 of the input circuit may be written as follows:

$$(5) \quad L_2 p I_1 + R_2 I_1 - mp I_2 = 0$$

Rewriting (4) and (5) respectively—

$$(6) \quad I_1(\mu R_2 - mp) + I_2(L_1 p + R_1) = 0$$

and

$$(7) \quad I_1(R_2 + L_2 p) - I_2(mp) = 0$$

The criterion for a real solution of (6) and (7) for I_1 and I_2 is—

$$(8) \quad (L_1 p + R_1)(R_2 + L_2 p) + mp(\mu R_2 - mp) = 0$$

The general solution of equations of the form of (6) and (7) for I_1 and I_2 will take the form:

$$(9) \quad I_1 = A_1 e^{\omega_1 t} + A_2 e^{\omega_2 t}$$

$$(10) \quad I_2 = B_1 e^{\omega_1 t} + B_2 e^{\omega_2 t}$$

$$(11) \quad \omega_1 = in - \delta$$

where in is an imaginary and δ is a real. The real quantity δ represents a damping factor.

For sustained sinusoidal oscillations, the general equation

$$(12) \quad I = e^{\omega t}$$

holds true.

Differentiating (12)—

$$(13)\quad pI=\omega e^{\omega t}=\omega I$$

and

$$(14)\quad p=\omega$$

From (11) it will be seen that in the case of sustained oscillations where the damping factor is zero

$$(15)\quad \omega_1=in$$

and since from (14)

$$(16)\quad \omega_1=p$$

it follows that—

$$(17)\quad p=in,\ p^2=-n^2,\ p^3=-in^3 \text{ etc.}$$

Consequently to make the damping factor or real portion of the exponent equal to zero, the even powers of p which are reals must drop out. Considering the criterion (8) and making the sum of the even powers of p in that equation equal to zero.

$$(18)\quad R_2L_1p+R_1L_2p+m\mu pR_2=0$$

and—

$$(19)\quad L_1L_2p^2-m^2p^2+R_1R_2=0$$

From (17) and (19)—

$$(20)\quad \frac{R_1R_2}{L_1L_2-m^2}=n^2=(2\pi f)^2 \text{ or } f=\frac{1}{2\pi}\sqrt{\frac{R_1R_2}{L_1L_2-m^2}}$$

Hence it appears that oscillations will be obtained when the resistances, inductances and mutual inductance of the circuit, and the internal resistance and amplifying power of the tube are related as in (18) and the frequency produced by the oscillator will depend upon the resistances, inductances and mutual inductance as shown by (20).

It should be noted that although the elements of the tube may constitute a small capacity, this plays no essential part in determining the generated oscillation frequency, especially at low frequencies.

Although the invention has been described and illustrated in the preferred form only, it is to be understood that it is not to be limited except as indicated by the scope of the appended claims.

What is claimed is:

1. An oscillation generator comprising a work circuit, an amplifier having input and output circuits, and a network of negligible capacity electrically associating said circuits to connect the output circuits in aiding relation to the input circuit, said network and circuits determining the frequency of the generated oscillations substantially solely by virtue of the resistance and inductance thereof.

2. An oscillator comprising a network, an amplifier associated therewith, said network comprising means whereby the network and amplifier transfer energy cyclically to each other at a predetermined periodicity determined substantially solely by the resistance and inductance of said amplifer and network.

3. A thermionic oscillation generator having an input circuit, an output circuit, and means to connect said output circuit in energy transfer relation to said input circuit, said circuits and connecting means having a negligible amount of capacity, the frequency of the generated oscillations being determined by the other electrical constants of said circuits and connecting means.

4. An oscillation generator comprising an amplifier and means for feeding back energy amplified by said amplifier to be reamplified, both said amplifier and said means having negligible capacity, the frequency of the generated oscillations being determined by the other electrical constants of said amplifier and energy feeding back means.

5. An oscillation generator comprising an amplifier having input and output circuits, said circuits together with said amplifier constituting a network for determining the frequency of the generated oscillations independent of any electrical capacity thereof.

6. An oscillation generator comprising a network, a prime source of energy, means whereby said source transfers energy periodically to one portion of said network and said portion simultaneously transfers energy to a second portion of said network the first energy transfer being under the control of said second energy transfer and the periodicity of said energy transfer action being determined substantially solely by resistance and inductance.

7. A reactive network adapted to transfer energy cyclically at a predetermined periodicity, said network having electrical constants of such value that the sum of the even power terms of the differential operator in its characteristic is zero and being non-resonant at said predetermined periodicity.

8. An oscillation generator comprising an amplifying device, and a network connected thereto, said network comprising resistance and inductance for determining the frequency of the oscillations generated, said network being non-resonant at frequencies of the order of the generated oscillations.

In witness whereof, I hereunto subscribe my name this 17th day of February A. D., 1919.

HAROLD W. NICHOLS.