April 12, 1938. W. VAN B. ROBERTS 2,114,114

OSCILLATORY SYSTEM

Filed Nov. 5, 1935

Fig. 1

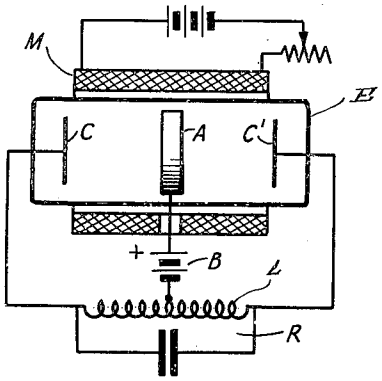


Fig. 2

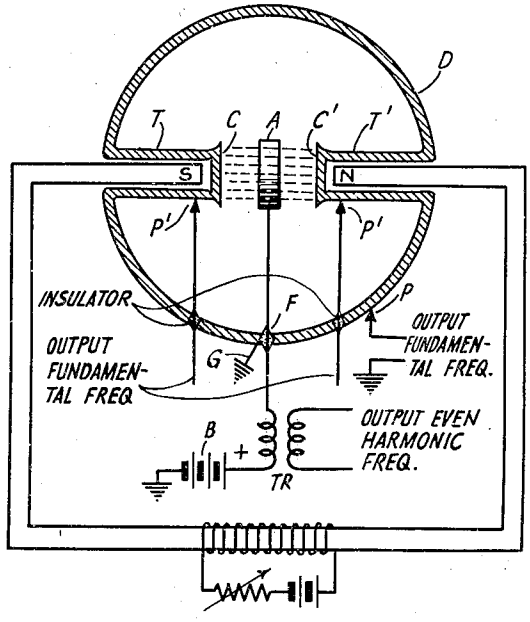


Fig. 3

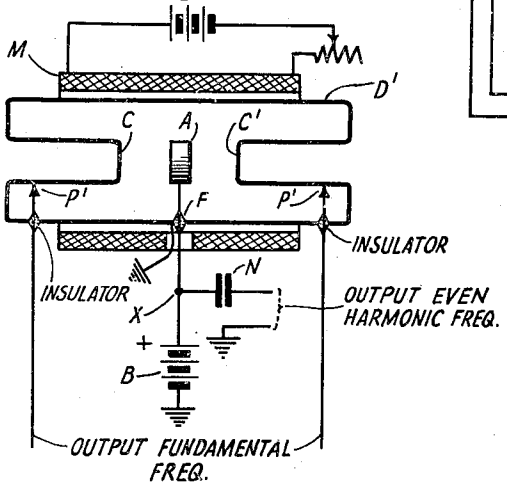


Fig. 4

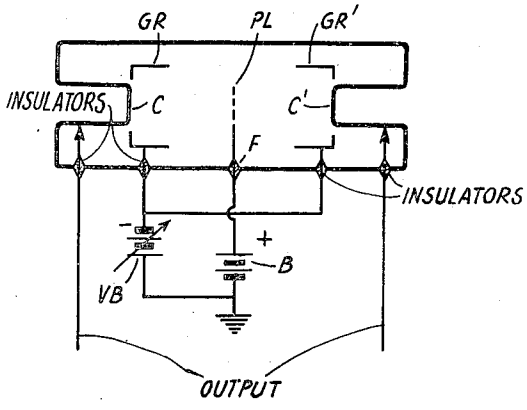
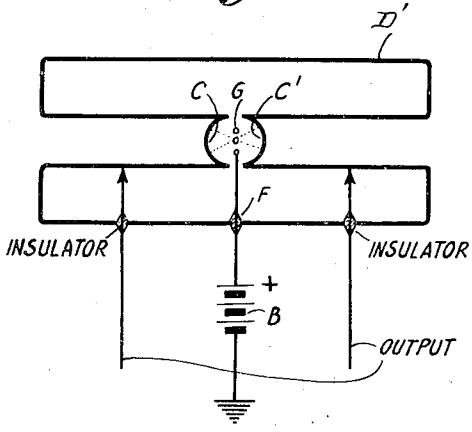


Fig. 5



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OSCILLATORY SYSTEM

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Application November 5, 1935, Serial No. 48,306

22 Claims. (Cl. 250—36)

This invention relates broadly to electron discharge device circuits, and particularly to such circuits which employ devices containing a pair of cold cathodes or dynodes functioning by means of secondary emission of electrons and oppositely disposed with respect to a central collecting electrode. The present invention is especially concerned with this type of device when used as an oscillation generator, hereinafter referred to as a double resonance oscillator.

In order that the present invention may be better understood, an explanation will first be given of the operation of a double resonance oscillator, with special reference to Fig. 1 of the accompanying drawing which illustrates this type of oscillator. The figure discloses a tube which has an evacuated envelope E enclosing a centrally located anode A in the form of a ring, and a pair of cold cathodes C, C' oppositely disposed with respect to the anode A. Cathodes C, C' are treated, or specially designed, to emit copious secondary electrons when bombarded by other electrons and are connected to the terminals of a resonant circuit R having an inductance L to whose midpoint is connected a battery B which maintains the anode A at a positive potential with respect to the cathodes. A coil M surrounds the envelope for producing a magnetic field perpendicular to the plane of the anode.

In the operation of the double resonance oscillator, an electron free to move in the envelope, produced by radioactivity, thermal agitation, photoelectric effect, or otherwise, will be accelerated toward anode A. Assuming that this free electron starts from a position near the surface of cathode C, it will travel along the magnetic lines of force of the field toward C' but will be prevented by the field from striking ring-like anode A. The electron will pass through the hole of anode A but will now be decelerated until it reaches or fails to reach C' according to whether the potential of C' is positive or negative. The time required for the electron to travel from C to C' is determined by the geometry of the tube structure and by the potential of battery B. Assuming that this time is one hundred-millionth of a second, and cathodes C, C are excited in opposite phase, either by shock excitation of the tuned circuit R or by an external alternating frequency source coupled to R, with a voltage whose frequency is fifty-million cycles per second and with an amplitude of fifty volts on each cathode, and that the electron previously considered arrives at C' at a moment when the potential of C' is positive and something like fifty volts, then the impact of the electron on cathode C' will dislodge a number of secondary electrons which will now be drawn back toward cathode C where they will arrive half a period (of the fifty megacycle frequency) later, that is, when C has become positive, thus dislodging a still greater number of secondary electrons, which will repeat the process of the first electron. This building up process continues until the space between electrodes contains so dense a cloud of electrons oscillating back and forth that in spite of the constraining magnetic field some of them are pushed over into the anode A, and equilibrium is established when the average absorption of electrons by the anode is equal to the net loss of electrons by secondary emission from the two electrodes C, C'. It will be observed that when one of the cold cathodes C or C' is positive, it suffers a net loss of electrons which constitutes a flow of current between the electrode and the resonant circuit contrary in direction to the flow that would be produced if the space within the tube were conductive in the ordinary fashion. In other words, the electrodes C, C' present a negative conductance to the terminals of the resonant circuit. As a result of this, energy is not absorbed from the resonant circuit by the tube, but is actually absorbed by the circuit from the tube. Hence, a tuned circuit as shown by R in Fig. 1, if started to oscillate sufficiently strong at its natural frequency will continue so to do if it absorbs energy from the tube faster than it dissipates energy in its own resistance, that is, if the average negative conductance of the tube measured between cathodes C and C' exceeds the positive conductance of the tuned circuit R measured at resonant frequency between its two ends. It will be observed that to obtain oscillations the battery B must be adjusted to make the frequency of electron oscillation within the tube substantially equal to the natural frequency of the tuned circuit R, and it is for this reason that such an oscillation generator is herein named a double resonance device. Similarly, throughout this specification, the electrodes C, C' presenting negative conductance by virtue of secondary emission will be called dynodes, following the nomenclature of A. W. Hull who first produced negative conductance by means of secondary emission.

An object of the present invention is to provide an improved double resonance oscillator for very short wave lengths.

A further object of the invention is to provide

an electron discharge device for generating short waves having a vacuum tight envelope which also acts as the oscillatory circuit of the oscillator.

A still further object is to provide an oscillatory circuit for the generation of short waves having portions thereof acting also as dynode electrodes of an electron discharge device.

According to the present invention, the resonant circuit is replaced by a tank or oscillatory circuit in the form of an evacuated metallic container having distributed inductance and capacity. This tank or oscillatory circuit is provided with a pair of inwardly projecting tubes or cylinders whose inner confronting surfaces are treated to act as dynodes.

In the accompanying drawing:

Fig. 1 illustrates diagrammatically a double resonance oscillator, given merely for the purpose of the foregoing exposition, and

Figs. 2, 3, 4, and 5 illustrate different embodiments of the invention.

Referring to Figs. 2 and 3 in more detail, there are shown double resonance oscillators functioning broadly on the principle outlined in connection with the system of Fig. 1. In Fig. 2 the oscillatory tank circuit comprises a metallic evacuated sphere D having inwardly projecting tubes T, T' whose inner confronting cold surfaces C, C' acting as cathodes or dynodes are oppositely disposed with respect to a centrally located anode A in the form of a ring. These dynodes are treated, or specially designed, to emit copious secondary electrons when bombarded by other electrons. The path for electrical oscillations is then from the end of an inwardly projecting tube, let us say T, out to the sphere D, around the sphere, and back in to the inner end of the other inwardly projecting tube T'. The ends of these inwardly projecting tubes are closed and form the dynodes for electron discharge phenomena exactly as shown in Fig. 1. Similarly as in Fig. 1, a collector ring anode A is maintained at a high positive potential by a battery B and brought out through the sphere D by way of a glass bead seal F. This seal is located in the plane of the collector ring which is a plane of neutral radio frequency potential on the sphere. The negative end of the battery B is connected to a point in this neutral plane, preferably close to the seal. In the drawing the ground connection G is shown a little off the neutral plane for the sake of simplicity of illustration, although in practice it is located directly behind the seal F.

Inside the hollow inwardly projecting tubes are located rods of high magnetic permeability forming pole pieces N and S for providing the magnetic circuit shown. If desired, permanent bar magnets may be used instead. In either case, the desired magnetic field between the dynodes C, C' which is substantially parallel to the axis of the collector A is produced, as shown by the dotted lines. If oscillations of an even harmonic frequency are desired, such oscillations may be taken off to a utilization circuit by way of transformer TR. Due to the opposing effect of the inner part of the oscillatory tank circuit, there will not be much potential drop along the sphere, but the finite spacing prevents complete neutralization at very high frequencies and there is also some drop due to the resistance of the sphere D, so that a certain amount of voltage is produced. Oscillations of fundamental frequency may be obtained from ground and a point P on the sphere D other than in the neutral plane, the distance from the neutral plane where the connection to the sphere is made depending upon the impedance of the output circuit to be energized. Balanced output may be taken between two such points on either side of the neutral plane. Larger voltages may be obtained by connecting to points within the sphere. For instance, balanced output may be obtained between points P', P' on the vacuum surface of tubes T, T' of the sphere symmetrically located with respect to the neutral plane by way of lecher wires, as shown.

Sphere D and cylinder tubes T, T' are made of low resistance metal such as copper, and the surfaces thereof toward the vacuum is made to be as smooth as possible, inasmuch as it is this surface that carries the greatest current density.

Fig. 3 shows a modification of Fig. 2 wherein the sphere D has been flattened down to form a cylinder D'. The magnetic field may be provided exactly as in Fig. 2, or, alternatively, a field coil M may be wound around the entire structure as shown. In this figure an alternative method for taking off energy at an even harmonic frequency is shown consisting of direct connections from ground and a point X on the lead connecting the collector A to the battery B, the distance along the anode lead depending upon the load impedance. At high frequencies this lead has sufficient impedance to produce a voltage drop of appreciable magnitude. A blocking condenser N is shown in the output connection to the anode lead. For fundamental frequency output or take-off, the load may be connected between the neutral plane and another point on the external cylinder, or between symmetrically located points, in similar fashion to the methods described in connection with Fig. 2.

By substituting a grid like element for the collection ring A, as shown in Figs. 4 and 5, more fully described in copending application Serial No. 46,980, filed October 28, 1935, by applicant and Charles H. Brown, the magnetic field may be dispensed with.

In Fig. 4, the usual ring anode is here replaced by a screen or perforated plate PL, and the dynodes C, C' are surrounded by guard rings GR, GR' maintained at a suitable potential, preferably somewhere near the average potential of the dynodes, by variable battery VB, so that the lines of electrostatic force from the dynodes C, C' to the collector anode PL are substantially parallel. Screen anode PL presents an area of solid matter which is so small relative to the area of the perforations that the collector PL will receive (prior to the time when any considerable space charge is built up within the tube) a lesser proportion of electrons passing therethrough than the ratio of gain of electrons at each impact to the number before impact. That is, if we consider a certain number of electrons about to strike the right hand dynode C', the collector PL must not receive as much as the total increase in number when the secondary electrons come back through it, otherwise the number of electrons oscillating within the tube would not build up. Best results will be obtained by using extremely fine wires for the collector electrode PL and making the mesh as coarse as possible without upsetting the uniformity of the electrical field in the space between collector PL and dynodes C, C'.

In Fig. 5, the dynodes or cathodes C, C' extend, as a surface which is somewhat spherical,

around a small fine grid structure G, which may even be a single wire. The dotted lines indicate the paths of the electrons which are not now parallel as in the previous structures of Figs. 1 to 4, inclusive. The feature of Fig. 5 is that the lengths of the paths of electrons from one dynode C to the other dynode C' are approximately the same, although there is a wide variety of these paths.

It will be understood, of course, that the invention is not limited to the precise details described in connection with the drawing since various modifications may be made without departing from the spirit and scope of the invention. The oscillator of the invention can be used in receivers as well as in transmitters, and in circuits similar to the manner of other known types of electron discharge device oscillation generators.

What is claimed is:

1. An electron discharge device comprising an evacuated metallic envelope constituting an oscillatory circuit and containing an inwardly projecting portion, the end of said inwardly projecting portion presenting a surface capable of emitting secondary electrons on impact of a primary electron, an electron collector element located between said surface and the surface of the envelope opposite thereto, and means for applying a positive potential to said collector element with respect to said surfaces.

2. Apparatus in accordance with claim 1, characterized in this that said collector element is in the form of a ring in a plane perpendicular to the path of travel of the electrons between said surfaces, thus presenting an unobstructed space for movement of electrons between said surfaces.

3. An electron discharge device comprising a metallic envelope containing an inwardly projecting portion, the end of said inwardly projecting portion and the portion of the envelope opposite said end presenting cold surfaces capable of emitting secondary electrons on impact of a primary electron, an electron collector element located between said surfaces and in a plane substantially perpendicular to the path of travel of the electrons between said surfaces, means for applying a positive potential to said collector element with respect to said surfaces, and means for applying a magnetic field between said surfaces which is perpendicular to the plane of said element.

4. In combination, an electron discharge device comprising an evacuated metallic envelope comprising as a part thereof a pair of surfaces capable of emitting electrons on impact, an element located substantially midway between said surfaces which element enables the passage of electrons between said surfaces, and a source of energy for maintaining said element at a positive potential with respect to said surfaces.

5. Apparatus in accordance with claim 4, characterized in this that said element is a grid.

6. In combination, an electron discharge device comprising a metallic envelope containing two oppositely disposed inwardly projecting portions, the confronting surfaces of which are capable of emitting secondary electrons on impact, an element located between said surfaces which enables the passage of electrons therebetween, and a source of energy for maintaining said element at a positive potential with respect to said surfaces.

7. An electron discharge device comprising a metallic envelope containing an inwardly projecting portion, the end of said inwardly projecting portion and the portion of the envelope opposite said end presenting surfaces capable of emitting secondary electrons on impact of a primary electron, an anode located between said surfaces, means for applying a positive potential to said anode with respect to said surfaces, and a coil surrounding said envelope for producing a magnetic field perpendicular to the plane of said anode.

8. An electron discharge device comprising a metallic envelope containing an inwardly projecting portion, the end of said inwardly projecting portion and the portion of the envelope opposite said end presenting surfaces capable of emitting secondary electrons on impact of a primary electron, an anode located between said surfaces, means for applying a positive potential to said anode with respect to said surfaces, and a magnet having pole pieces of opposite polarity adjacent said surfaces for producting a magnetic field perpendicular to the plane of said anode.

9. In combination, an electron discharge device comprising an evacuated metallic envelope comprising as a part thereof a pair of surfaces capable of emitting electrons on impact, an element located between said surfaces which enables the passage of electrons between said surfaces, a source of energy for maintaining said element at a positive potential with respect to said surfaces, and means for applying a field which is perpendicular to the plane of said element.

10. In combination, an electron discharge device comprising an evacuated metallic envelope comprising as a part thereof a pair of surfaces capable of emitting electrons on impact, an element located between said surfaces which enables the passage of electrons between said surfaces, an external source of energy, a connection from said element to the positive terminal of said source, a connection from said envelope to the negative terminal of said source, means for insulating said first connection from said envelope, and an output circuit coupled to said first connection.

11. In combination, an electron discharge device comprising a metallic envelope containing two oppositely disposed inwardly projecting portions, the confronting surfaces of which are capable of emitting secondary electrons on impact, an element located between said surfaces which enables the passage of electrons therebetween, a source of energy for maintaining said element at a positive potential with respect to said surfaces, and an output circuit comprising a pair of connections in contact with said inwardly projecting portions.

12. Apparatus in accordance with claim 11, characterized in this that said pair of connections are lecher wires adjustable over said projections and extending from within said container externally thereof, said lecher wires being insulated from said envelope at the points of egress.

13. Apparatus in accordance with claim 1, characterized in this that said metallic envelope is in the form of a sphere, except for the inwardly projecting portion.

14. In combination, an electron discharge device comprising a metallic envelope containing two oppositely disposed inwardly projecting portions, the confronting surfaces of which are capable of emitting secondary electrons on impact, an element located between said surfaces which enables the passage of electrons therebetween, a guard ring surrounding the periphery of each surface for producing lines of electrostatic force

which are substantially parallel from the surfaces to the element, and a source of energy for maintaining said element at a positive potential with respect to said surfaces and guard rings.

15. In combination, an electron discharge device oscillator comprising an evacuated metallic envelope comprising as a part thereof a pair of cold surfaces capable of emitting electrons on impact, an element located between said surfaces which enables the passage of electrons between said surfaces, a source of energy for maintaining said element at a positive potential with respect to said surfaces, and means for obtaining output energy from said oscillator.

16. In combination, an electron discharge device comprising a metallic envelope containing two oppositely disposed inwardly projecting portions, the confronting surfaces of which are capable of emitting secondary electrons on impact, said surfaces being substantially spherical in form, a grid located between said surfaces, and a source of energy connected to said grid for maintaining same at a positive potential with respect to said surfaces.

17. An electron discharge device comprising an enclosed metallic envelope constituting an oscillatory circuit having therein as part of said envelope, a pair of cold electron emitting electrodes adapted to maintain oscillations in said circuit, said cold electrodes being treated to produce copious secondary electrons upon impact with other electrons, and an electron collecting element located between said electrodes.

18. An electron discharge device comprising an evacuated metallic envelope constituting an oscillatory circuit and containing an inwardly projecting portion, the end of said inwardly projecting portion presenting a surface capable of emitting secondary electrons on impact of a primary electron, an electron collector element in the form of a planar grid located substantially midway between said surface and the surface of the envelope opposite thereto, said grid being in a plane substantially perpendicular to the path of travel of the electrons between said surfaces, and means for applying a positive potential to said collector element with respect to said surfaces.

19. An electron discharge device comprising a metallic envelope containing an inwardly projecting portion, the end of said inwardly projecting portion and the portion of the envelope opposite said end presenting cold surfaces capable of emitting secondary electrons on impact of a primary electron, an electron collector element located substantially midway between said surfaces and in a plane substantially perpendicular to the path of travel of the electrons between said surfaces, means for applying a positive potential to said collector element with respect to said surfaces, and means for applying a magnetic field between said surfaces which is perpendicular to the plane of said element.

20. In combination, an electron discharge device comprising an evacuated metallic envelope comprising as a part thereof a pair of surfaces capable of emitting electrons on impact, an electron collecting element located substantially midway between said surfaces, said element being in a plane substantially perpendicular to the path of travel of electrons between said surfaces, and a source of energy for maintaining said element at a positive potential with respect to said surface.

21. In combination, an electron discharge device comprising an evacuated metallic envelope comprising as a part thereof a pair of surfaces capable of emitting electrons on impact, an electron collecting element located substantially in the center of said envelope and between said surfaces which enables the passage of electrons between said surfaces, an external source of energy and a connection from said element to the positive terminal of said source, a connection from said envelope to the negative terminal of said source, means for insulating said first connection from said envelope, and an output circuit coupled to said first connection.

22. An electron discharge device comprising an enclosed metallic envelope constituting an oscillatory circuit and having as part thereof a pair of cold electron emitting electrodes, said cold electrodes being treated to emit copious secondary electrons upon impact with other electrons, and an electron collecting element located substantially midway between said electrodes and in a plane substantially perpendicular to the path of travel of the electrons.

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