July 13, 1937. A. L. SAMUEL 2,086,579

ELECTRON DISCHARGE DEVICE

Filed April 27, 1934

FIG. 1

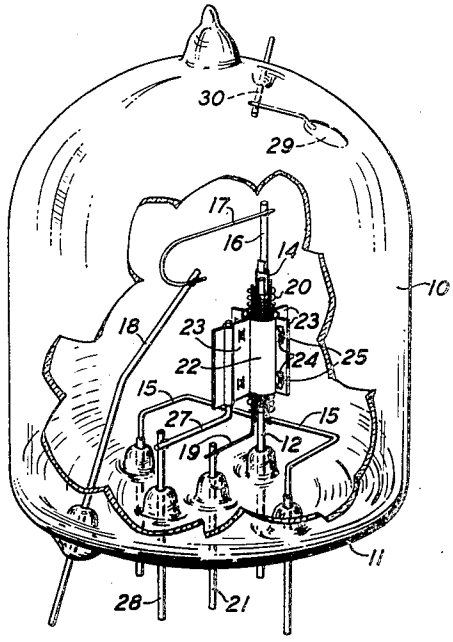


FIG. 3

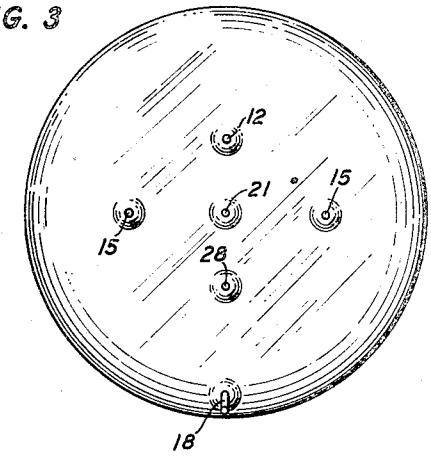


FIG. 2

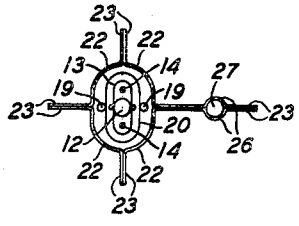
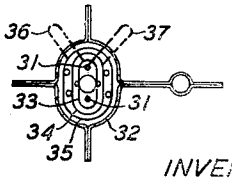


FIG. 4



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ELECTRON DISCHARGE DEVICE

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6 Claims. (Cl. 250—21.5)

This invention relates to electron discharge devices and more particularly to such devices adapted for the generation of ultra-high frequency oscillations and of the type generally known as electron coupled oscillators.

One object of this invention is to isolate the elements which determine the frequency at which the device is to oscillate from the elements of the device included in the output circuit.

Another object of this invention is to increase the power output and oscillation efficiency of high frequency oscillation generators.

In one embodiment of this invention, an electron discharge device comprises a cathode, an outer anode, and two perforate or grid electrodes between the cathode and anode. The perforate or grid electrode nearest the cathode is operated at a negative potential and serves as the control electrode. The other perforate or grid electrode serves as an inner anode and is operated at a positive potential usually of less magnitude than the positive potential of the outer anode. The cathode, control grid and inner anode are associated through an external circuit, the tuning of which determines the frequency at which the device oscillates. The outer anode is coupled to one of the first three electrodes to provide an output circuit.

In accordance with a feature of this invention, the electrodes are designed and spaced so that the capacitance effect between the two anodes is substantially neutralized by the capacitance effect between the control electrode and the outer anode.

In accordance with another feature of this invention, the electrodes are so spaced and designed that under operating conditions, the electron transit time to the inner anode is small, preferably substantially negligible, while the transit time of an electron between the inner and outer anodes is relatively large and of the order of a half period of the frequency at which the device is intended to oscillate.

The invention may be embodied also in an electron discharge device comprising five electrodes, namely, a cathode, an anode and three perforate or grid electrodes between the cathode and anode. The perforate or grid electrode nearest the cathode serves as a control electrode, the next as an inner anode, and the third as a suppressor or control electrode.

The third or outermost of the perforate or grid electrodes, if used as a control electrode, is connected to the inner control electrode and is positioned and designed so that its capacitance to the outer anode compensates for the capacitance between the inner and outer anodes.

If used as a suppressor electrode, the third or outermost of the perforate or grid electrodes may be connected to the cathode and so designed and positioned that its capacitance to the outer anode compensates for the capacitance between the control electrode and the outer anode.

The invention and the features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a perspective view of an electron discharge device illustrative of one embodiment of this invention, portions of the enclosing vessel being broken away to show the electrode assembly more clearly;

Fig. 2 is an enlarged end view of the electrodes showing the configuration and relative position thereof;

Fig. 3 is a diagrammatic view showing the position of the electrode leading-in conductors with respect to one another; and,

Fig. 4 is a diagrammatic end view showing the position and configuration of the electrodes in an electron discharge device having five electrodes and constructed in accordance with this invention.

Referring now to the drawing, the electron discharge device shown in Fig. 1 comprises an evacuated enclosing vessel **10** having a base wall **11** from which a cathode, an anode, and two perforate or grid electrodes are mounted. The perforate or grid electrode nearest the cathode is intended to be operated as a control electrode, and the other perforate or grid electrode is intended to be operated as an anode.

The inner grid or perforate electrode, which may be of the general construction described and claimed in my copending application, Serial No. 722,704, filed April 27, 1934, comprises a central linear metallic support or rod **12** sealed in the base wall **11** of the enclosing vessel and carrying an oval or flattened helical grid **13**, each of the longer sides of each turn of the grid **13** being suitably secured, as by welding, to the central support or rod **12**.

The grid **13** encompasses a hairpin or elongated U-shaped filamentary cathode **14**, for example of thoriated tungsten, the arms of the cathode being disposed on opposite sides of the support or rod **12**. Each arm of the cathode is secured to a rigid bent wire or rod **15** sealed in the base wall **11** of the enclosing vessel. The cathode is supported at its other or upper end

by a hook member 16 secured to one end of a flexible J-shaped member or spring 17, which is carried by a metallic support or rod 18 sealed in the base wall 11 adjacent the periphery thereof.

The grid 13 is encompassed by a perforate inner anode comprising a pair of parallel metallic uprights or wires 19 carrying an oval or flattened helical grid 20 which is uniformly spaced from the grid 13. One of the uprights or wires 19 is secured to a rigid support or wire stub 21 sealed in the end wall 11 of the enclosing vessel.

The outer anode comprises four sections each including an arcuate portion 22 forming an oval member uniformly spaced from the grid 20, and flanges 23, the flanges on adjacent sections being disposed in face to face relation and secured together by bent integral tabs 24 on one flange extending through apertures 25 in the adjacent flange. Two of the flanges are provided with flutes or grooves 26 forming a channel in which an arm of a bent support or rod 27 extends, the support or rod being suitably secured to these flanges, for example, by welding. The other arm of the support or rod 27 is secured to a rigid wire or rod 28 sealed in the base wall 11 of the enclosing vessel.

A metallic disc 29 having a getter material, such as magnesium, thereon is supported from a stub 30 sealed in the top portion of the enclosing vessel. During the fabrication of the device, the disc and getter 29 may be heated, for example, by high frequency induction, whereby the getter is vaporized to fix residual gases in the enclosing vessel 10.

The circuit including the control electrode 12, 13 and the inner anode 19, 20 may be tuned to the frequency at which the device is desired to oscillate; the circuit including the outer anode may be tuned to obtain the maximum operating efficiency. It will be seen, therefore, that the cathode, control electrode and inner anode constitute a three-electrode oscillator from which electrons are released at periodic intervals to the outer anode, the periodicity being determined by the tuning of the circuit including the three first mentioned electrodes.

In order to effectively segregate the output circuit from the frequency determining element so that variations in the load will not affect the tuning, it is desirable that the outer anode be coupled to the other electrodes only by the electron stream. In accordance with this invention, this is attained by designing and positioning the electrodes so that under operating conditions, the alternating potential appearing on the inner anode, by virtue of the capacitance existing between it and the outer anode, is substantially neutralized by the potential appearing on the control electrode, by virtue of the capacitance existing between the control electrode and the outer anode. In other words, the electrodes are of such configuration and design, and are so spaced that the capacitance between the inner and outer anodes is compensated for by the capacitance between the control electrode and the outer anode. The capacitance between electrodes in an electron discharge device may, of course, be ascertained in ways well known to those skilled in the arts.

The operating characteristics of an electron discharge device at extremely high frequencies are materially dependent upon the transit times of electrons between the various electrodes of the device. Preferably the cathode and inner anode are so spaced that in the range of potentials at which the inner anode is operated, the electron transit time between these electrodes is so small as to be substantially negligible. With this condition, more electrons leave the cathode during that portion of the cycle when the control electrode is in the positive half of its potential excursion and the total work per electron for this period is negative.

In the region between the inner and outer anodes, it has been found that for any value of electron transit angle some relative phase exists between potentials on the inner and outer anodes for which the total work per electron is negative. Furthermore, it has been found that the maximum total work is substantially independent of the transit angle for values of the transit angle up to π. Hence, it is very desirable, in order to obtain a relatively high output and operating efficiency, that the transit time of an electron between the inner and outer anodes be relatively large and of the order of a half period of the frequency at which the device is intended to operate.

The invention is not limited to electron discharge devices of the specific construction shown and described hereinbefore. The features thereof may be embodied in devices having more than four electrodes. In one modification, illustrated in Fig. 4, an electron discharge device comprises a cathode 31, an anode 32, and three oval, helical or perforate electrodes 33, 34 and 35 disposed between the cathode and anode. The electrode 33 may be utilized as the control electrode and the electrode 34 as an inner anode usually operated at a potential of less magnitude than the potential of the outer anode 32.

The electrode 35 may be connected to the control electrode 33 as indicated schematically by the line 36, and so designed and positioned that the capacitance between it and the outer anode compensates for the capacitance between the inner and outer anodes. When used connected to control electrode 33, the electrode 35 produces an increased bunching of the electrodes which enter into the region between the inner and outer anodes and thus serves to increase the efficiency of the device. It will also serve to suppress secondary electrons so that the device may be operated with larger potential variations on the anodes than would otherwise be possible.

The electrode 35 may be utilized also as a suppressor electrode, in which case it is connected to the cathode, as indicated schematically by the line 37, and is designed and positioned so that its capacitance to the outer anode compensates for or substantially neutralizes the capacitance between the control electrode and the outer anode.

Although specific embodiments of this invention have been shown and described, it will be understood, of course, that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron coupled oscillator comprising an anode and a frequency determining element operatively associated with said anode including a cathode, a control electrode and an anode, said control electrode and said anodes being so constructed and arranged that when proper potentials are applied to said first anode and to the electrodes of said frequency determining element to produce a periodic release of electrons from said frequency determining element to said first anode, the potential appearing upon said first

anode by virtue of the capacitance between said anodes is substantially neutralized by the capacitance appearing upon said first anode by virtue of the capacitance between said control electrode and said first anode.

2. An electron coupled oscillator comprising a frequency determining element including a cathode, a control electrode and an anode, and another anode adapted to be coupled to said frequency determining element to receive electrons therefrom at periodic intervals, said control electrode and said anodes being so constructed and arranged that the capacitance between said anodes is of substantially the same magnitude as the capacitance between said control electrode and said another anode.

3. An electron coupled oscillator comprising a frequency determining element including a cathode, a helical control electrode encompassing said cathode, and a perforate anode encompassing said control electrode, and a second anode encompassing said perforate anode, said control electrode and said anodes being so constructed and arranged that the capacitance between said anodes is of the same order of magnitude as the capacitance between said control electrode and said second anode.

4. An electron discharge device comprising a cathode and an anode constituting elements of an oscillator system, and an output electrode in said device and spaced from said anode a distance of the order of one-half wave-length of the frequency of said oscillator system.

5. An electron discharge device comprising a cathode, a control electrode and an anode constituting elements of an oscillator system, said anode being disposed in immediate proximity to said cathode so that at the resonant frequency of said system the electron transit time between said cathode and said anode is substantially negligible, and an output electrode in said device and spaced from said anode a distance such that the transit time between said anode and said output electrode is of the order of one-half period of said resonant frequency.

6. An electron discharge device comprising a cathode, a control electrode encompassing said cathode, a perforate anode encompassing said control electrode, said cathode, control electrode and perforate anode constituting elements of an oscillator system, and an output anode outside of said perforate anode, in said device and said perforate anode being disposed in such proximity to said cathode that the electron transit time between said cathode and said perforate anode is substantially negligible, and said output anode being so disposed relatively remote from said perforate anode that the electron transit time between said anodes is of the order of one half the period of the frequency of said oscillator system.

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