Nov. 3, 1936. P. T. FARNSWORTH 2,059,683

SCANNING OSCILLATOR

Filed April 3, 1933 2 Sheets-Sheet 1

Fig. 1.

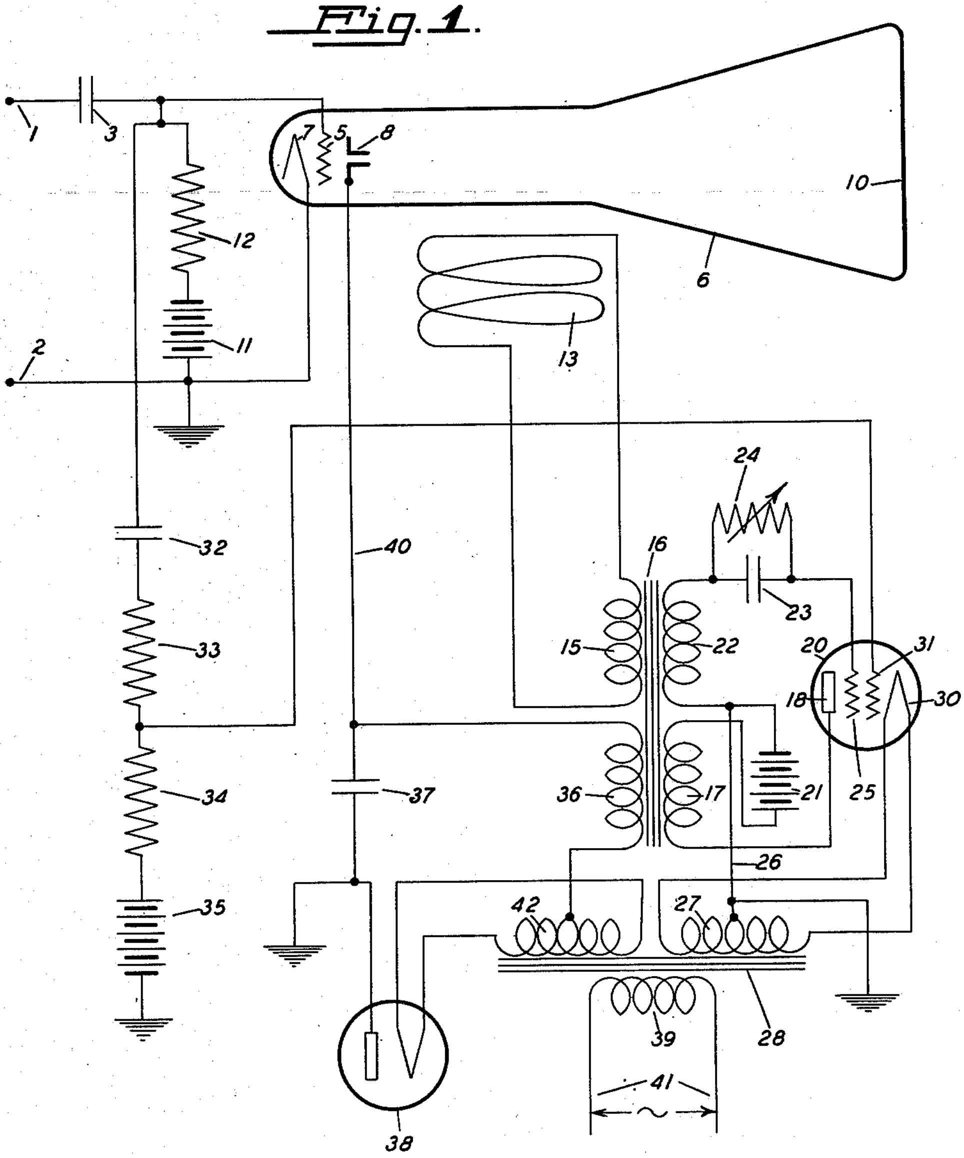

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Fig. 2.

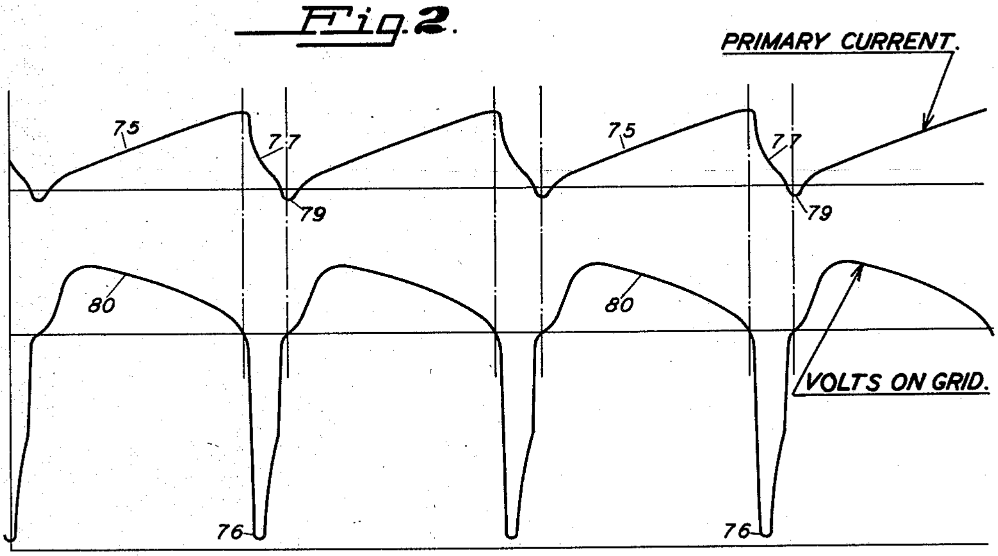
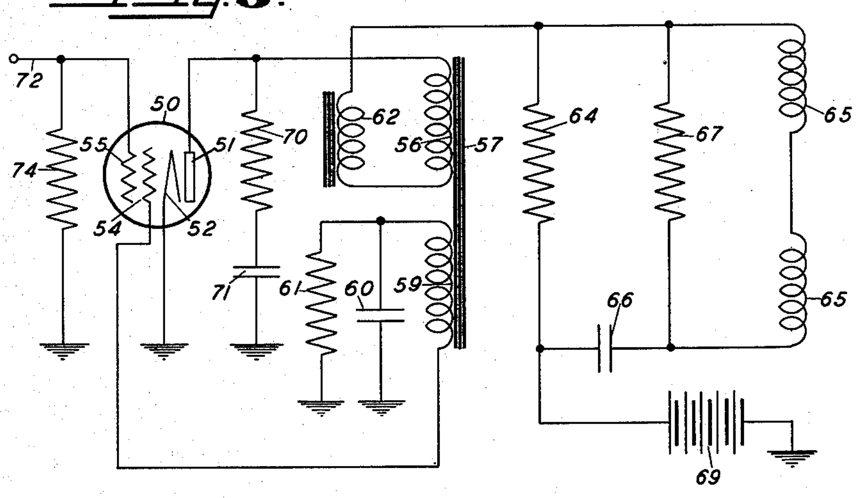


Fig. 3.



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UNITED STATES PATENT OFFICE

2,059,683

SCANNING OSCILLATOR

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Application April 3, 1933, Serial No. 664,180

6 Claims. (Cl. 250—36)

This invention relates to oscillators for producing non-sinusoidal waves of predetermined form, and particularly to oscillators for producing waves having a portion of substantially constant slope, for producing scanning fields in cathode ray television equipment. This application is a continuation in part of my copending application, Serial No. 550,654, filed July 14, 1931.

Among the objects of this invention are: to provide a type of oscillator suitable for producing either the high frequency or the low frequency scanning field for cathode ray television equipment, depending upon the electrical constants of the design; to provide an oscillator for producing non-sinusoidal or "saw-tooth" waveforms which are not dependent upon ionization phenomena; to provide an oscillator for television use having stable and predeterminable characteristics; to provide an oscillator which will fall into step readily with a synchronizing pulse; to provide an oscillator wherein the natural curvature of the waveform may be corrected to produce a wave characterized by a substantially straight line form over a major portion of its cycle; and to provide an oscillator whose frequency characteristics are substantially independent of resonance, and whose waveform is controllable, externally of the tube, within wide limits.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but I do not limit myself to the embodiment of my invention herein described, as various forms may be adopted within the scope of the claims.

Referring to the drawings:

Figure 1 is a circuit diagram illustrating the oscillator of my invention as applied to the supply of high frequency scanning current for a television receiving system.

Figure 2 comprises graph showing the waveform of plate current and grid potential in one embodiment of the invention.

Figure 3 is a circuit diagram of the oscillator as utilized to supply low frequency scanning fields.

Considering the invention broadly, it comprises a vacuum tube of the hot-cathode type, preferably provided with an additional grid or control electrode through which synchronizing impulses are applied to the oscillator. Included in the plate circuit of the tube is the primary of a transformer, preferably with an iron core and a secondary adapted materially to over-control the grid. With low mu tubes this involves a material step-up ratio, while with tubes having a high amplification constant the ratio may be unity or less, but in any case the primary and secondary circuits should be non-resonant. The secondary is connected to the grid of the tube and is so poled that an increase in plate current will drive the grid strongly positive. Biasing for the grid is preferably provided by a relatively large condenser bridged by an adjustable grid leak.

Coupled into the plate circuit, either directly in series, or through the same transformer as is used for coupling grid and plate, is an impedance element which may be the useful work circuit of the tube, or may be a corrective element provided for the sole purpose of controlling the waveform. As will be explained below, where the object of the oscillator is to produce saw-tooth current waves having a substantially linear increase in current during a major portion of the cycle, this corrective element takes the form of an iron core inductance, wherein the core exhibits saturation phenomena within the range of the current flow through the tube. Where other types of waveform are desired this corrective element may, of course, be given other characteristics. The usual plate supply is, of course, provided.

The fundamental characteristics of this oscillator arise through the coupling between grid and plate. The high step-up ratio of the transformer causes the tube to "dump" or "flop". That is, the tube acts almost purely as a switch. When a voltage is first applied to the plate, and current starts to flow, a high positive potential appears on the control grid, causing the tube to exhibit minimum impedance. Under these conditions, the current flow in the plate circuit is conditioned primarily by the impedance external to the tube, or at least external to the plate circuit, and the grid circuit itself acts as a load on the plate circuit which reduces its impedance for so long a time as the grid continues to draw current. When saturation in the tube or any other cause operates to decrease the amount of plate current, the grid promptly swings negative, causing a further decrease in plate current, which again reflects into the grid circuit, so that the flow is interrupted practically instantly. This reestablishes open circuit conditions in the plate circuit, after which the cycle repeats.

It is obvious that the performance of this device will be greatly modified by the conditions within the load and corrective circuits, but before considering this in detail two embodiments of the invention will be described, and the effects producible will be taken up as affected by the conditions obtaining in these embodiments.

The embodiment shown in Figure 1 illustrates the application of the invention as used to supply high frequency scanning potentials in a television receiving system, as is described in my copending application, Serial No. 550,654, above mentioned. A television signal, comprising picture impulses interspersed with scanning pulses is supplied through the leads 1 and 2, the lead 1 being connected through a grid condenser 3 to the control electrode 5 of an oscillight or cathode ray television receiver tube 6, while the lead 2 connects to the cathode 7 of the tube. The perforated anode 8 accelerates electrons from the cathode to form a cathode ray beam which impinges upon a fluorescent screen formed on the face 10 of the tube. The grid 5 is biased by a battery or other source 11 through a grid resistor or leak 12.

The beam is deflected by a magnetic field produced by a deflecting coil 13, and the oscillator which is the subject of this invention supplies the current for this coil through the medium of a winding 15 which is one of several coupled by a ferro-magnetic transformer core 16.

The primary coil 17 of the transformer has one end connected to the plate 18 of the vacuum tube 20, the other end of the winding being connected in series with a suitable plate supply 21, and thence to ground. A secondary winding 22, having a material step-up ratio as compared with the primary 17, connects through a relatively large grid condenser 23, bridged by an adjustable leak 24, with the control grid 25 of the tube. The ground lead 26, which is connected to both the low potential end of the winding 22 and the negative side of the plate supply, also connects to the center tap on a winding 27 of a filament transformer, the winding being linked with the core 28 and feeding the cathode 30 of the vacuum tube 20.

The tube is preferably supplied with an auxiliary grid 31 which connects through a blocking condenser 32 and resistor 33 with the grid 5 of the oscillight. A positive bias is applied to the auxiliary grid, through a resistor 34, by a battery or other source 35 whose negative end also connects to ground.

As is described in my copending application above identified, a portion of the output of the oscillator is preferably utilized to supply anode potential for the oscillight. An additional winding 36 on the coupling transformer connects through a condenser 37 to the grounded plate of a diode 38. The cathode of this diode is supplied by a winding 42 on the filament transformer, the high potential winding 36 connecting to a mid tap on the winding 42. The filament transformer is provided with a primary 39, connected to the ordinary alternating current supply leads 41. The anode circuit of the oscillight may therefore be traced from the high potential side of the winding 36, through a lead 40 connecting with the anode 8 of the oscillight, from the oscillight filament to ground, and thence from the ground back through the diode 38 to the low potential side of the winding 36. The function of the diode is, of course, to rectify this current, while the condenser 37 functions as a filter under the conditions described. This portion of the equipment is fully described and claimed in the copending application previously referred to.

The embodiment of the invention shown in Figure 3 is that preferred for supplying the low frequency scanning current. In this diagram the filament circuits have been omitted, since they are essentially similar to those shown in the first figure and the resultant simplification in the drawing increases its clarity. In this figure, the tube 50 is similar to the tube 20 of the first figure, having a plate 51, cathode 52, grid 54, and auxiliary synchronizing grid 55.

The plate 51 connects to the primary 56 of a step-up transformer 57, whose secondary 59 is connected to the grid 54. The low potential end of the secondary is connected to ground, the grid condenser 60 and grid leak 61 being in this instance interposed in the ground side of the circuit.

In series with the primary 56 is an iron core inductance 62, preferably of the order of 150 henries in the absence of a D. C. component, and having a core of sufficiently small cross-section so that the inductance is greatly reduced under conditions of maximum plate current. A one inch square silicon steel core has proved satisfactory for this purpose.

The plate current is supplied to the tube through a resistor 64, across which there is bridged a scanning circuit comprising the coils 65 in series with a blocking condenser 66 of about ten microfarads capacity. In practice the resistor 64 has a value of about 15,000 ohms, while that of the scanning coils is approximately 8,000 ohms. A resistor 67, preferably of considerably higher value than that of resistor 64 is bridged across the coils, this resistor being just low enough in value to prevent impact oscillations being set up in the coils during the steeper slope portion of the current wave. The circuit is supplied from a source 69 whose negative end is grounded.

In order to prevent undue stress on the insulation of the transformer and on the tube it is usually desirable to connect a resistor 70 in series with a condenser 71, from the plate 51 to ground. This circuit is in the nature of a safety valve or relief by-pass, and its constants depend upon the maximum potential which may safely be permitted on the plate of the tube.

A synchronizing pulse may be applied to the tube through the lead 72, which is shown as connected to ground to a grid leak 74.

We may now consider the detailed operation of the invention in connection with Figure 3. Starting with the cathode excited, as the plate circuit is first closed, a current will start to flow in this circuit, the potentials provided by the battery being divided across the scanning coil circuit, the inductor 62, primary 56, and the tube. In the ordinary oscillator at least half and usually more of the potential drop will occur in the tube, but in the present instance, owing to the high step-up ratio of the transformer, the grid 54 at once swings so strongly positive that the tube itself becomes of minimum impedance, and the major voltage drop occurs in the external circuit. During this initial portion of the cycle the grid may be much more strongly positive than the plate, and the major current flow from the cathode may actually be to the grid instead of the plate. This imposes a relatively large load on the transformer, decreasing its effective primary impedance, with the result that the major voltage drop in the plate circuit occurs across the inductance 62, whose voltage drop exceeds all the rest of the circuit elements put together.

The inductance permits a gradually increasing current to flow, but this current at once begins to saturate the core, which decreases the effective reactance in the circuit and consequently permits a constantly increasing voltage to appear on the plate. In the meantime the condenser 60 has started to charge due to the flow of grid current, and during the ensuing portion of the cycle the plate continues to grow more positive and the grid less positive, so that the filament current is gradually transferred from the grid to the plate. Were the inductance 62 an air core device, so that the inductance remained at substantially constant value, the rate of increase in the plate current would gradually fall off, but owing to the saturation effect in the inductance and the decreased effective plate resistance of the tube due to the higher voltage applied thereto, this condition is corrected or compensated, and the period of increasing current is characterized by a substantially constant rate of change as is shown by the portion 75 of the upper graph of Figure 2.

It will be noted that throughout this period there will also be a substantially constant rate of increase in the current in the scanning coils. Although these coils represent a large number of turns, their air core construction and the relatively low rate of change of the current therein, renders them a primarily resistive load. At a scanning frequency of say 24 to 25 cycles, the inductive component of these coils cannot be relied upon to control the waveform.

The end of this increasing portion in the cycle occurs when saturation current effects begin to manifest themselves within the tube. There then arrives the transition point when the plate current ceases to increase. The positive charge imposed upon the grid by the transformer thereupon disappears, and the negative charge which has been accumulated by the condenser 60 can take its full effect, causing an actual decrease in plate current. This causes a further negative charge to be imposed upon the grid 54 by the transformer, so that the tube immediately "dumps", a tremendously high negative potential pulse appearing on the grid as indicated by the portion 76 of the lower curve of Figure 2. The plate current is blocked completely, although it does not fall off instantly owing to the tremendous voltage pulse tending toward its continuation which appears in the plate circuit due to its high inductance. It is the function of the resistor 70 and condenser 71 to limit the value of this pulse. The decrease in plate current takes the form shown by the portion 77 of the upper graph. The discharge of the condenser 60 through the transformer causes the slight negative pulse 79 in the primary current, and the cycle repeats when this current again reaches zero. The grid voltage throughout the increasing portion of the cycle is shown by the positive portion 80 of the grid voltage curve, this voltage rising to a maximum and then falling off when the condenser 60 charges and discharges.

It is to be noted that in this oscillator the grid circuit exercises a double function. That is, it not only serves to apply the usual control voltages to the grid, thus controlling the impedance of the plate circuit internally of the tube, but it also imposes a load upon the plate circuit which causes impedance changes in that circuit externally of the tube. The grid condenser, moreover, adds to its usual function of producing a bias on the grid that of controlling the phase angle of the load thus imposed. The interactions produced by this double functioning render the anlysis and description of the operation exceedingly complex, since the actions are concurrent and each function affects the other. It follows from these facts that there are several possible methods of description of the operation, all equally true, but differing primarily in emphasis. The one adopted here is merely that in which the emphasis is directed most strongly toward the factors which determine the design of equipment for producing a predetermined waveform, i. e., the corrective reactance of the primary circuit and the phase or load control in the grid circuit.

The elements present in the circuit of Figure 3 are also present in the circuit of Figure 1, but in this case, instead of the various elements of the circuit being included in series with the transformer primary, their effect is introduced into that circuit through the transformer coupling. The controlling inductance, which limits and defines the rate of change of the primary current, is that of the deflecting coil 13. To this may be added the leakage reactance 16 of the transformer, and if the transformer core be worked at high saturation values, a great deal of the effect of the separate iron core inductance may be introduced. It is to be noted that at the higher frequency used with the transverse scanning, the inductive effect of the coils themselves may well be ample to control the rate of change in the primary current. The grid condenser 23 and grid leak 24 have the same effect as the grid condenser 60 and grid leak 61 of Figure 3, although they occupy a different position in the circuit. The function of the resistor 70 and condenser 71 is filled by the winding 36 and its associated circuits, comprising the diode 38 and the space circuit of the cathode ray tube 6.

The natural frequency of each of the two forms of oscillator is controlled by adjusting the value of the grid leak, thus determining the phase of the grid circuit load and the time required for the grid condenser to charge to a sufficiently high value to start the "dumping" action of the tube. Irrespective of this setting, however, the appearance of a negative pulse of sufficiently high value on the auxiliary or synchronizing grid will start the action, holding the oscillator in step even though the frequency of the synchronizing pulses may depart very materially from the natural frequency setting of the device. The frequency may also be controlled by regulating the voltage of the plate supply.

It will be obvious that by changing either the grid circuit impedance, the corrective impedance, or both, entirely different waveforms could be generated in an oscillator of this type. Resistance or capacity in the plate circuit will completely alter the rate of change in the plate current, while an inductive load in the grid circuit would cause the grid voltage to rise as the cycle progressed instead of fall. It would appear unnecessary to go into the various modifications possible with the combination described, since the effect of various types of impedance elements is well known.

Both forms of waveform control are utilized in each of the modifications of the oscillator here shown. In the low frequency type of oscillator the plate circuit form of correction is utilized more fully than in the high frequency type, since the requirements are somewhat less rigorous on the higher frequency equipment, and it is easier to utilize a smaller portion of the saturation current of the tube, thus avoiding the tendency toward curvature in the waveform, than it is to carry the increasing current portion of the cycle toward the limit and correct for the curvature. In the high frequency type of oscillator the impedance of the grid condenser to the fundamental frequency should be low, a condenser of approximately $\frac{1}{10}$ microfarad being suitable for frequencies of two to three thousand cycles, the grid leak having an impedance about one order of magnitude greater than the condenser at the fundamental frequency. At the frequencies used in the forms shown in Figure 3 this would require a 10 microfarad grid condenser, which would be unduly bulky. A smaller grid condenser is therefore used, with a grid leak of such value as to give the required time constant, and the distortion which would otherwise ensue from this departure from optimum values is compensated for by the saturation effect in the corrective impedance.

Perhaps the greatest advantage of the type of oscillator here described is the fact that it provides the sudden break-down characteristics which are usually found in gas conduction tubes with the stability and reproducibility of high vacuum tube phenomena. Very satisfactory saw-tooth waves may be produced with tubes of the glow discharge type when proper conditions of pressure and temperature obtain, but these factors vary so much with use and even with surrounding temperature that it is extremely difficult to obtain consistent results therewith. The oscillator of the present invention, however, will operate consistently for long periods, and is not affected materially by change of tubes, and it is in this, almost as much as in its wide flexibility of waveform, that its advantage lies.

I claim:

1. The method of controlling the waveform delivered by a vacuum tube oscillator having grid and plate circuits which comprises transferring energy from said plate circuit to said grid circuit in degree and ratio to provide an induced grid voltage in excess of that required to provide maximum plate current, and varying the impedance of said plate circuit both internally and externally of the tube by control of the phase and magnitude of said grid current.

2. The method of generating current waves of non-sinusoidal forms with a vacuum tube having an external impedance connected to the elements thereof which comprises using said tube effectively as a switch to permit or prevent the flow of current therethrough, and controlling the amount of said flow externally of said tube, by varying the impedance external to the tube to maintain the rate of increase of said current substantially constant throughout a major portion of each cycle.

3. The method of generating current waves of non-sinusoidal forms with a vacuum tube having grid and plate circuits associated therewith which comprises transferring energy from said plate circuit to said grid circuit in phase and ratio such that small increases in current in said plate circuit will produce minimum tube impedance therein and small decreases in said plate current will produce substantially complete cutoff, controlling the rate of change of said current externally of said tube, and utilizing the amount of said current as a factor in the control of the rate of change thereof by varying the impedance external to the tube to maintain the rate of increase of said current substantially constant throughout a major portion of each cycle.

4. The method of generating current waveforms having substantially constant rates of increase during a major portion of the cycle with a vacuum tube oscillator which includes the step of causing a sufficiently large current flow to the grid of the tube at the beginning of said portion of the cycle to create minimum tube impedance and transferring said flow to the plate of the tube as the cycle progresses.

5. An oscillator for providing currents of sawtooth wave form comprising an iron-core transformer comprising a grid coil and a plate coil of different natural periods, a vacuum tube having a plate connected to said plate coil and a grid, a condenser connected in series with said grid and grid coil, said grid and plate coils being proportioned and phased so that any increase of potential on said grid is cumulatively effective to produce maximum positive potential thereon, and a resistor bridged across said condenser, the impedance of said condenser and resistor being sufficiently low to provide an inappreciable bias to said grid except when a large proportion of the space current of said tube is flowing thereto.

6. An oscillator for producing currents of sawtooth wave form comprising a vacuum tube including cathode, anode and control electrodes, a predominately inductive plate circuit connecting said anode and cathode, a predominately inductive output circuit coupled to said plate circuit, means for impressing potential changes on said control electrode of opposite sign from changes occurring on the anode and of such magnitude that any change of potential of the one is cumulatively effective to produce maximum opposite change of potential on the other, a condenser of low impedance to the desired frequency of oscillation connected in series with said control electrode, and a resistor bridging said condenser and having an impedance not exceeding one order of magnitude greater than that of said condenser.

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