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TUNING FORK DRIVING MEANS

Filed June 6, 1938

3 Sheets-Sheet 1

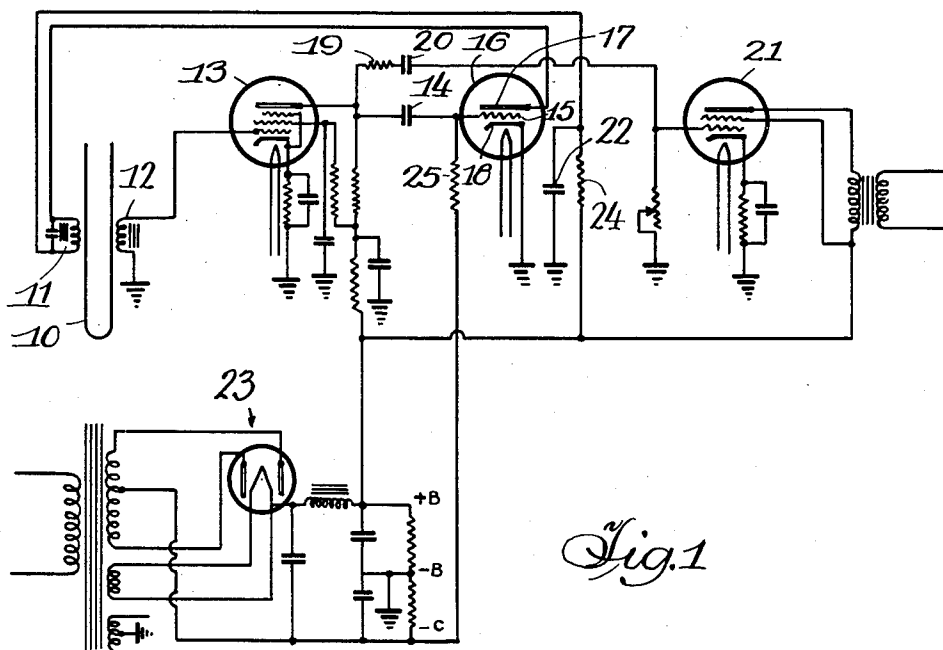


Fig. 1

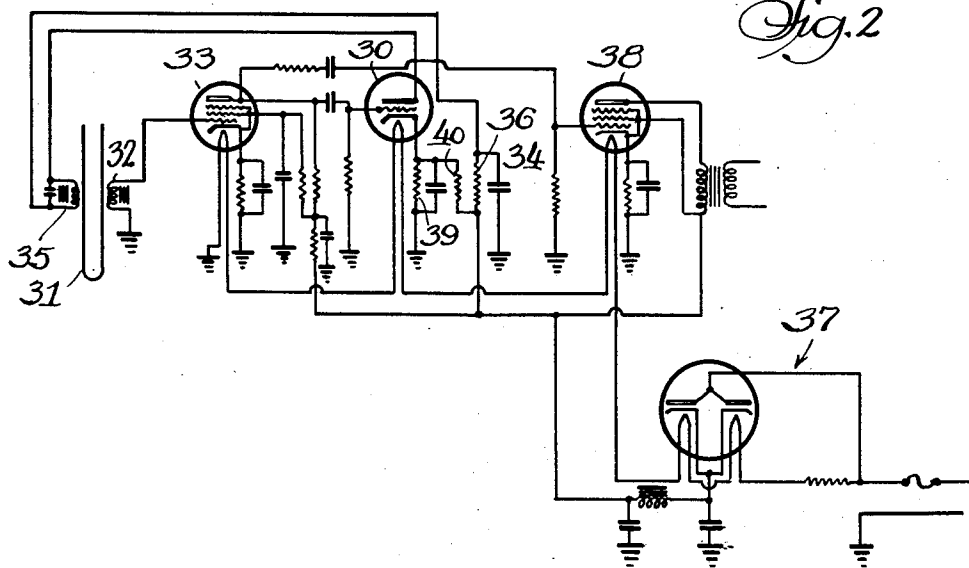


Fig. 2

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Fig. 3

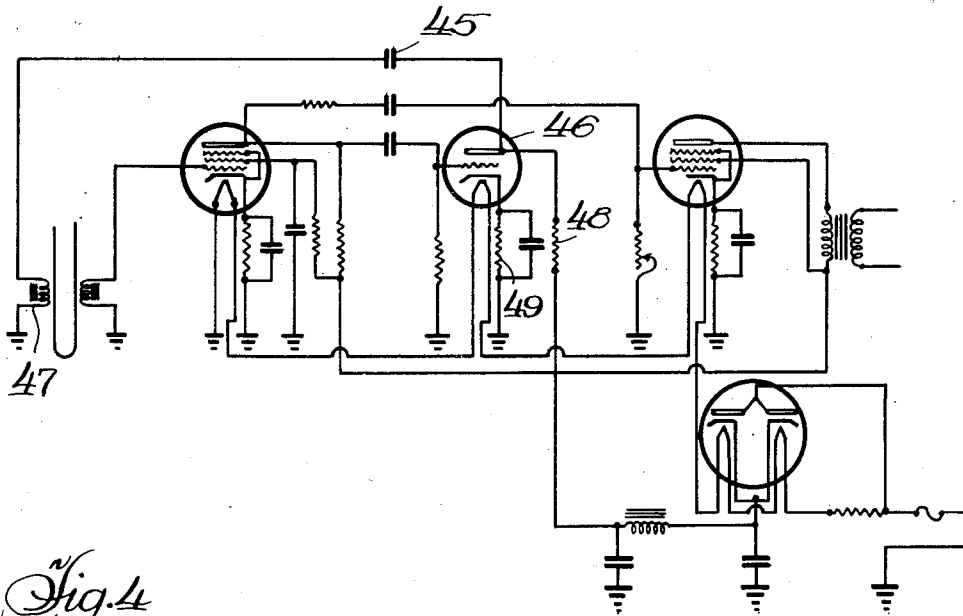
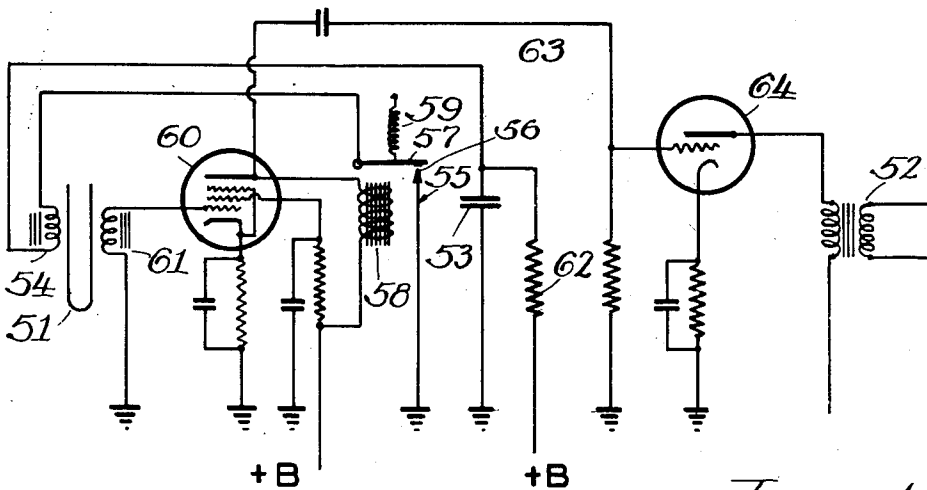


Fig. 4



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Fig. 5

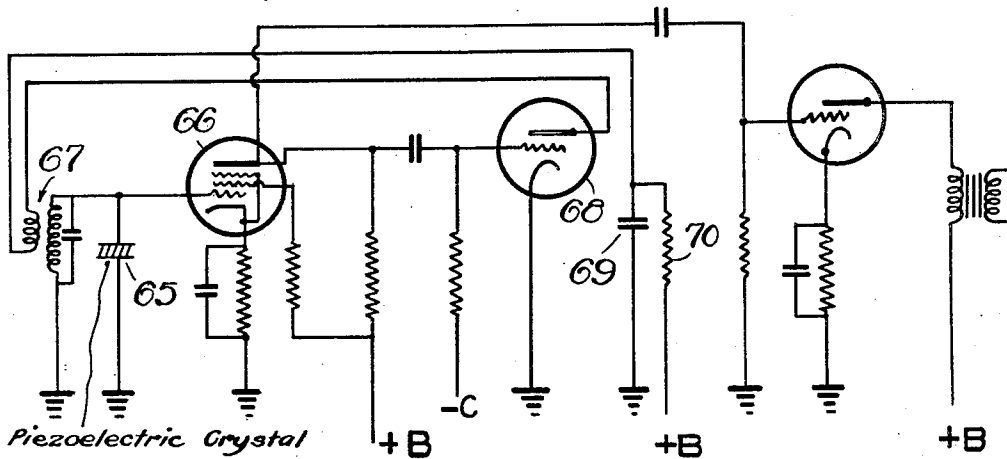
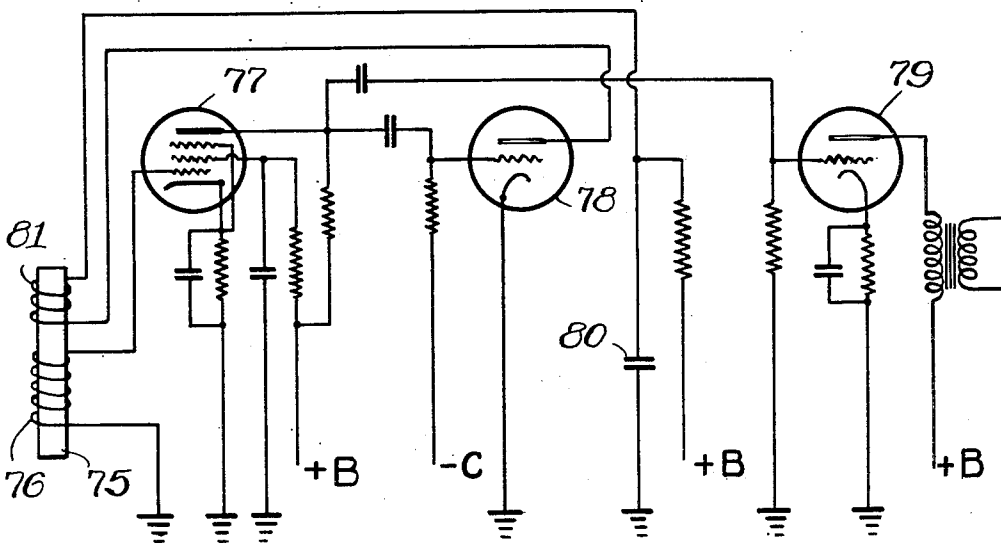


Fig. 6



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UNITED STATES PATENT OFFICE

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TUNING FORK DRIVING MEANS

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6 Claims. (Cl. 250-36)

This invention relates to tuning fork driving means and more particularly to improved means for maintaining a fork or other vibratory element in unvarying vibration.

One feature of this invention is that it is adapted to maintain a vibratory element in vibration at an unvarying frequency; another feature of this invention is that it enables generation of an oscillatory electric current of unvarying frequency, controlled by the mechanical vibration of said element; yet another feature of this invention is that an unvarying quantity of electrical energy is delivered to the driving means for the vibratory element at periodic intervals; a further feature of this invention is that initiation of the flow of the electrical energy is controlled by vibration of the vibratory element, but the quantity of electrical energy delivered to the driving means is independent thereof; other features and advantages of this invention will be apparent from the following specification and the drawings, in which:

Figure 1 is a schematic diagram of apparatus embodying my invention; Figure 2 is a schematic diagram of a modified form of my invention; Figure 3 is a schematic diagram of still another form of this invention; Figure 4 is a schematic diagram of a circuit including a relay; Figure 5 is a diagram of this invention applied to drive a piezo electric crystal; and Figure 6 shows its application to a magnetostrictive element.

In order to synchronize or correlate various elements it is frequently desirable to generate an oscillatory electric current of a predetermined unvarying frequency, and mechanical vibration of a vibratory element such as a tuning fork is frequently used to effect generation and frequency control of such a current. Such apparatus may be used, for example, in synchronizing sending and receiving apparatus of the character used in transmitting pictures by radio or wire, watch timing apparatus, and other commercial applications.

The period of vibration of a vibratory element such as a tuning fork is dependent, to some extent, upon the amplitude of its vibrations. That is, if the amplitude of vibration of a fork varies, the frequency varies slightly inversely therewith, being greater when the amplitude is less, and vice versa.

In order to maintain a tuning fork, for example, in sustained vibration for considerable periods of time, it is necessary to supply it at periodic intervals with driving energy, and this is generally accomplished by electrical means. I have found that conventional means for supplying a fork with driving impulses deliver a quantity of energy, at each impulse, which varies somewhat from time to time; and that as a

result the desired unvarying vibration of the tuning fork is not maintained. This is particularly true of the types of driving means wherein reactive build-up is present, magnifying any variations.

I have devised means for maintaining a tuning fork, under a set of standard conditions, in unvarying vibration by designing driving apparatus which furnishes to the fork at the desired periodic intervals impulses of an unvarying quantity of energy. I accomplish this by providing trigger or control means for initiating flow of energy to the driving means at the same point of each oscillation thereof, by means for supplying the driving energy which is, after initiation of the flow, independent of the control means and so arranged as to supply only a predetermined definite and unvarying quantity of electrical energy. In the embodiments of my invention disclosed herewith I use an electric tube, relay, or equivalent means as the trigger or control means, and a condenser for furnishing an unvarying quantity of electrical energy.

In the particular embodiment of my invention illustrated in Figure 1 a tuning fork 10 is diagrammatically illustrated in operative relation to a driving means or coil 11 and to a coil 12 affected by vibration of the fork and adapted to generate an oscillatory electric current or voltage as a result thereof. The coil 12 is connected to the grid of a conventional amplifying tube 13, adapted to amplify the oscillatory current and develop it in the plate circuit. Two subsequent paths are provided for these amplified oscillations: the first is through the blocking condenser 14 to the grid 15 of the electronic tube 16, this tube having a plate 17 and a cathode 18; and the other path is through the resistor 19 and blocking condenser 20 to the grid of another conventional amplifying tube 21, the output of this tube furnishing the desired electrical current for conventional commercial use.

A condenser 22, adapted to be charged in the manner to be more fully described hereinafter, provides the source of an unvarying quantity of electrical energy for energizing the driving coil 11 to deliver an impulse of unvarying energy to the tuning fork 10; and the tube 16 serves as the means to control initiation of the flow of energy. The condenser 22, the driving coil 11, and the plate and cathode of the tube 16 are connected in series to form the driving circuit; and the coil 12 is operatively connected to the grid 15, through the means previously described, to provide the control or trigger circuit.

A conventional source of supply voltage, here shown as a power pack indicated in general as 23, is adapted to furnish the plate voltage for the various tubes, and the charging current for the condenser 22. Maintenance of the requisite

plate potential on the plate of the tube 16, and charging of the condenser 22, is effected through a high resistance element 24 having one end connected to the driving circuit between the condenser and the plate 17, and the other end connected to the source of positive high voltage from the power pack 23. This element 24 should have a high resistance compared to the combined cathode-plate impedance of the tube 16 and the impedance of the driving coil 11, preferably being about the maximum permitting approximately fully charging the condenser 22 in about half a cycle, in accordance with the well known relations between the capacity of the condenser, the charging voltage, and the desired time interval.

The various constants of the circuits, as the impedance of the tube 16, capacitance of the condenser 22, resistance of the element 24, and the like, are so chosen that the condenser is adapted to completely, or substantially completely, discharge in a time interval of one-half cycle or less of the vibrations of the fork 10; and to be fully charged, to the voltage of the power pack or similar source, during one-half cycle or less of the fork. The grid of the tube 16 is biased in any desired way to a point at or near cut-off of the particular tube, so that during the negative half of oscillations of the grid current thereof substantially no space current flows between the cathode 18 and plate 17; but so that during at least some part of the positive half of such oscillations current is free to flow between said two elements. This biasing is here shown as effected by a voltage delivered from the power pack through a resistor 25.

Vibration of the tuning fork generates an oscillatory voltage in the coil 12 which, after being amplified by tube 13, is impressed on the grid 15 of the tube 16, this being so arranged that substantially no space current flows in the tube 16 during the negative half of this oscillation. During this negative half, therefore, the voltage impressed by the power pack through the resistor 24 cannot effect a current flow in the tube 16, but instead charges the condenser 22. When the other or positive half of the grid oscillation has reached a point where the tube 16 is capable of passing current, the condenser 22 discharges through the drive coil 11 and the space path of the tube. Because of the relatively high resistance of the element 24, however, a practically negligible proportion of the space current flow in the tube 16 during the positive half of such oscillations is the result of the plate voltage delivered by the power pack, so that practically all of the energy delivered to the coil 11, and thus to the tuning fork 10, results from the discharge of the condenser 22. Since the capacitance of the condenser does not change, and it is always charged to a definite voltage, the quantity of electrical energy delivered by the discharge thereof is unvarying.

The grid of tube 16 is swung to such a high amplitude that during the positive half of the grid voltage oscillations there is a certain margin above the grid swing that is necessary to completely discharge condenser 22. This prevents any slight decrease in grid voltage amplitude from causing a weaker drive impulse. Any increase in positive grid swing can, of course, deliver no more energy than is contained in the condenser. Therefore, despite any swings of the grid voltage which may take place, the driving impulses furnished to the tuning fork remain of unvarying energy.

In the modified form of my invention illustrated in Figure 2, the same desirable results are achieved in substantially the same way as the circuit illustrated in Figure 1, the principal difference being in the manner of biasing the grid of the control tube 30.

In a manner similar to that previously described, vibrations of the tuning fork 31 generate an oscillatory current in the coil 32, which current is amplified by the tube 33 and impressed on the grid of the control tube 30 to control the discharge of the condenser 34 furnishing the energy for the driving element or coil 35. Recharging of the condenser 34 is effected through the high resistance element 36 having positive voltage supplied thereto by the power pack indicated in general as 37. A portion of the oscillatory grid current is diverted and amplified by the tube 38 to furnish current for synchronizing or other purposes.

Rather than relying upon self-biasing or other methods of maintaining the grid of the tube 30 negative with respect to the cathode thereof, positive means supplied with voltage by the power pack 37 are here illustrated as including the resistors 39 and 40. These resistors form a voltage divider leading from the source of positive plate voltage to the ground, the cathode of the tube 30 being connected intermediate the ends of the divider, as by being connected to the junction point of the two resistors. The cathode is thus raised to a positive potential above ground by an amount, with respect to the B-voltage proportionate to the ratio of the resistor 39 to the sum of the two resistors. This has been found to provide an exceptionally stable and effective manner of maintaining the bias of the tube at or near cut-off.

The embodiment of the invention illustrated in Figure 3 is quite similar in major respects to that illustrated in Figure 1, the principal difference being that the condenser 45 supplying the driving energy is connected between the plate of the control tube 46 and one side of the driving coil 47, rather than being connected from the coil to ground; various resistors, however, being considerably different than they would be in conventional amplifier circuits. That is, the resistor 48 is preferably about one megohm, as contrasted with 25,000 ohms; and the resistor 49 is about 250,000 ohms, as contrasted with a usual value of about 1500 ohms in a self-biasing resistor.

In the embodiment of this invention illustrated in Figure 4, the essential elements of the circuit for driving a tuning fork 51 and using the oscillatory voltage generated thereby to drive some load connected to the output are illustrated. In this form the trigger element, adapted to control initiation of the discharge of the condenser 53 through the drive coil 54, is a relay 55. This relay comprises a contact point 56 adapted to cooperate with the movable armature 57 and an energizing coil 58. The movable armature is normally biased out of contact with the point 56, as by a spring 59.

The energizing coil 58 of the relay is in the plate circuit of the tube 60, forming part of the means connecting the coil 61 to the relay. The flow of plate current in the tube 60, as a result of grid voltage generated in the coil 61 by movement of the tuning fork 51, develops a voltage across and current through the energizing coil 58. When the flow has reached a definite predetermined point, the movable armature 57 closes the circuit including the contact point 56, 75

the driving coil 54, and the condenser 53, and the latter discharges to provide the driving impulse for the tuning fork.

As described in connection with the preceding embodiments, the condenser 53 is adapted to be recharged at appropriate intervals through the resistance element 62; and a part of the output of the tube 60 is diverted, through the lead 63, to the tube 64, where it is further amplified and delivered to the output 52.

A further modification of my invention is illustrated in Figure 5, the circuit here being designed and adapted to drive a piezo electric crystal. This arrangement can, for example, provide much better frequency control of the carrier wave frequency of transmitting stations.

In this embodiment of the invention the piezo electric crystal 65, forming the vibratory element, has one side thereof connected to the grid of the tube 66, and to one end of the secondary of a transformer 67. The other side of the crystal, and of the transformer, are effectively connected together by being connected to chassis ground.

The tube 68 serves as a trigger tube, the cathode plate space current path thereof being in series with the primary of the transformer 67 and the condenser 69 furnishing the driving impulses as a result of being charged through the resistor element 70. Sufficient feed back is permitted to cause the circuit to oscillate, and once it has started oscillating the crystal 65 is driven by the energy delivered to it by the secondary of the transformer 67, and in turn regulates the frequency of the oscillations impressed on the grid of the tube 66, and thus on the remainder of the system. At a predetermined point on the positive portion of the grid swing of the tube 68, the condenser 69 starts to discharge and continues discharging until the predetermined quantity of energy has passed through the primary of the transformer 67, and thus has been impressed as a driving force on the piezo electric crystal element 65.

Figure 6 illustrates a method of driving a magnetostrictive vibratory element 75 by definite and unvarying quantities of energy. The coil 76 has an oscillatory voltage generated therein by vibration of the element 75, which voltage is amplified in the tube 77 and partly delivered to the trigger tube 78 and partly to the further amplifying tube 79. The trigger tube 78, in accordance with the methods previously described, controls delivery of the energy content of the condenser 80 to the driving coil 81 serving to keep the element 75 in vibration.

While electronic tubes of the grid control type are here illustrated, it will be understood that any mechanism capable of "trigger" action could be substituted therefor, other common forms being "Thyratrons", "Ignatrons", relays, and the like. Similarly, although the condenser 45 is shown, it might be replaced by any device capable of furnishing a measured quantity of electrical energy at periodic intervals. That is, my invention lies in driving a tuning fork or other vibratory element such as a piezo electric crystal, magnetostrictive element, or the like, by the periodic application of impulses of a measured, unvarying energy content, initiation of each flow of energy being controlled by means responsive to vibration of the fork.

While I have shown and described certain embodiments of my invention, it is to be understood that it is capable of many modifications. Changes, therefore, in the construction and arrangement may be made without departing from the spirit and scope of the invention as disclosed in the appended claims, in which it is my intention to claim all novelty inherent in my invention as broadly as permissible, in view of the prior art.

I claim:

1. Apparatus of the character described for maintaining unvarying vibrations of a vibratory element, including: a driving element for furnishing driving impulses to said vibratory element, said driving element being adapted to be electrically actuated; an electronic tube having its cathode-plate circuit connected to said driving element to control the initiation of the flow of electricity therethrough; means affected electrically by vibration of said vibratory element connected to the grid of said tube, whereby initiation of said flow is coordinated with vibration of said vibratory element; a condenser connected to said driving element and said tube for delivering, upon initiation of flow by said tube, a predetermined substantially unvarying quantity of electrical energy; and means for charging said condenser with said quantity of electrical energy between flow periods.

2. Apparatus of the character claimed in claim 1, wherein the various constants of the circuits are so chosen that said condenser discharges in one-half cycle or less of the vibration of said vibratory element and is recharged before each cycle is completed.

3. Apparatus of the character described for maintaining unvarying vibrations of a vibratory element, including: a driving element adapted to be electrically actuated for furnishing driving impulses to said vibratory element; an electronic tube having a cathode, grid, and plate; a condenser; a circuit including in series said driving element, said condenser, and the cathode and plate of said tube; means whereby the vibration of said vibratory element generates an oscillatory current; a second circuit including in series said means and the grid of said tube, said second circuit including means biasing said tube so that substantially no current flows between the cathode and plate thereof during the negative half of each oscillation of said grid current; and means for charging said condenser, said means being so arranged that substantially all of the current flowing between the cathode and plate of said tube during the positive half of each oscillation of said grid current is the result of the discharge of said condenser.

4. Apparatus of the character claimed in claim 3, wherein said last mentioned means comprises a source of high voltage connected through a high resistance element to said first circuit between said condenser and the plate of said tube.

5. Apparatus of the character claimed in claim 3, including means for diverting and amplifying a portion of said oscillatory grid current.

6. Apparatus of the character claimed in claim 3, wherein said charging means includes a source of high voltage and said biasing is effected by said source.

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