June 1, 1926. 1,587,084

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CIRCUITS FOR ELECTRON DISCHARGE DEVICES

Filed Nov. 1, 1920 2 Sheets-Sheet 1

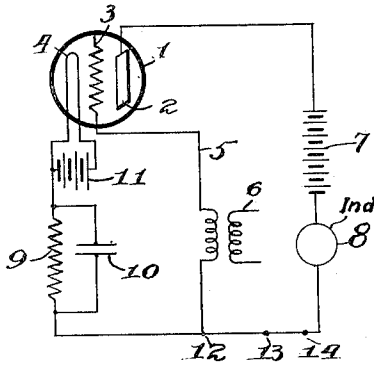


Fig. 1.

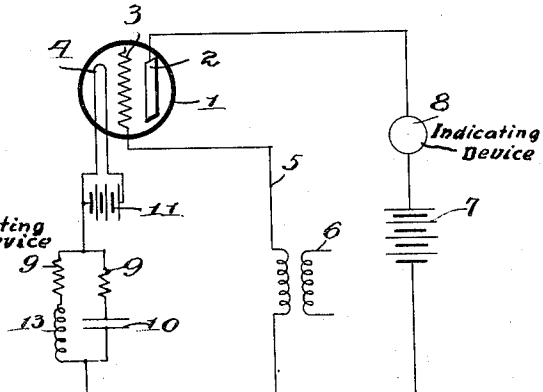


Fig. 2.

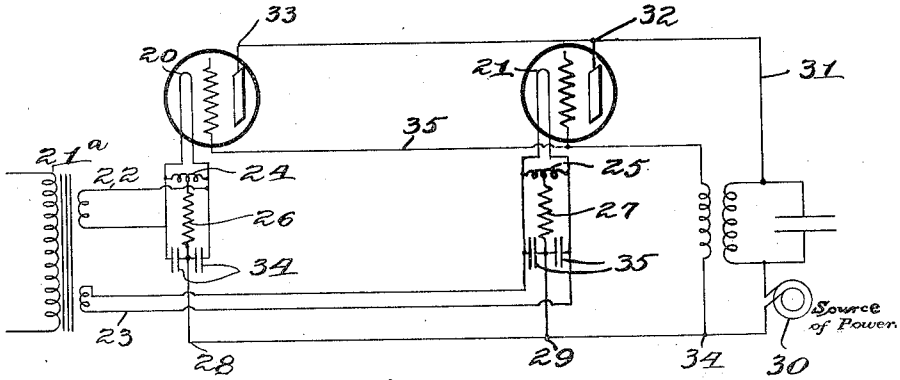


Fig. 3.

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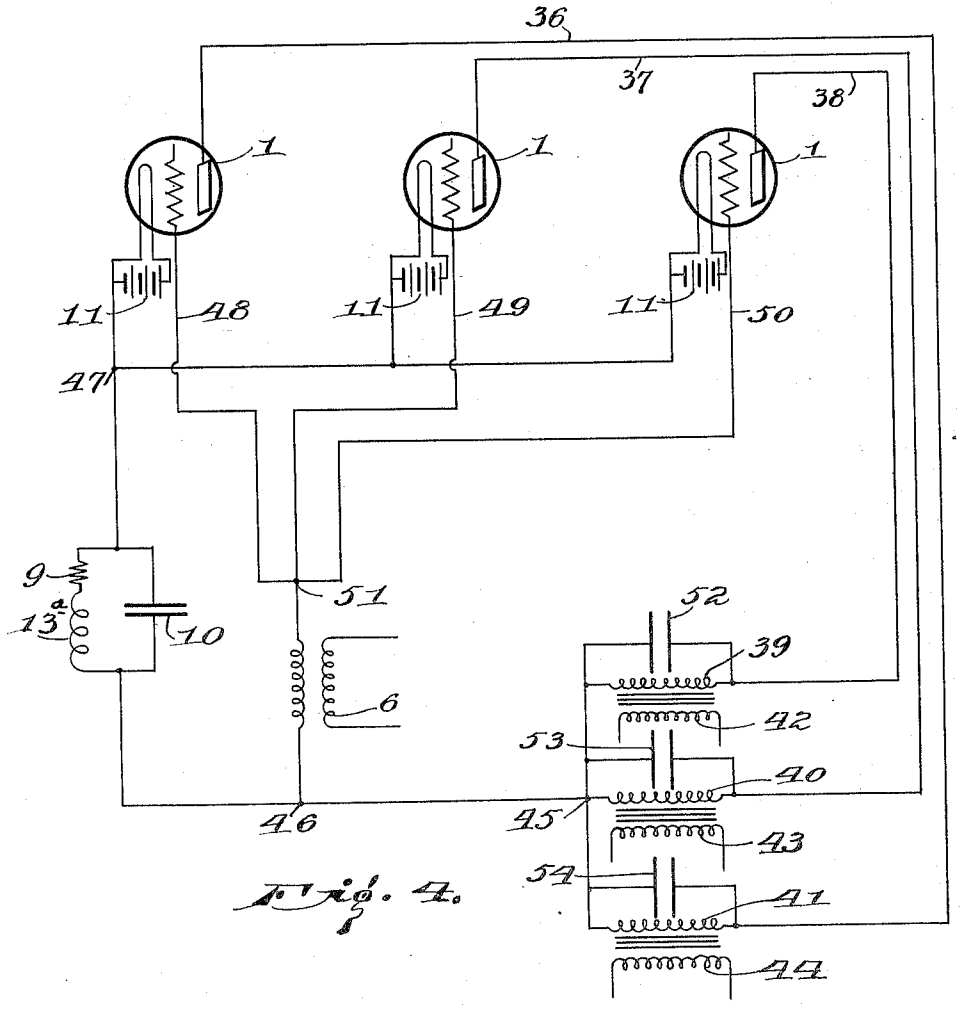


Fig. 4.

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Patented June 1, 1926. 1,587,084

UNITED STATES PATENT OFFICE.

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CIRCUITS FOR ELECTRON DISCHARGE DEVICES.

Application filed November 1, 1920. Serial No. 421,027.

The present invention relates to methods and means for controlling potentials and current flowing in circuits associated with the electron discharge devices. In one form the invention consists in an arrangement of circuits in connection with an electron discharge device in which the value of a varying current is regulated by means of a regulating current or potential which in itself has a varying regulating action on the controlled current depending upon the frequency and decrement of the controlled current or potential.

The present invention contemplates the utilization of an arrangement of circuits associated with electron discharge devices in which a modifying or regulating effect of a regulating current or potential is utilized to prevent variations of the control current or potential at certain definite frequencies while regulating to a lesser extent changes in the controlled current or potential at other frequencies. The modifying or regulating effect of the regulating current or potential may also be utilized to prevent variations of the control current or potential except at certain predetermined frequencies.

It is an object of the present invention to provide an arrangement of circuits associated with an electron discharge device whereby a regulating potential is superimposed upon the actuating grid potential.

It is a further object of the present invention to provide an arrangement of circuits associated with electron discharge devices whereby a regulating potential is superimposed upon the actuating grid potential, the regulating potential having a variable value in accordance with the frequency and decrement of the current flowing in one of the associated circuits.

It is a still further object to provide an arrangement of circuits associated with electron devices in which the plate circuits are energized from an alternating current supply, and a regulating potential is superimposed upon the grid potential for the purpose of minimizing the low frequency variations in plate current.

The present invention contemplates the use of any form of electron discharge device having one or more anodes, one or more cathodes and one or more control members such as a grid, the electron discharge device preferably being of the type in which the slope of the internal characteristic is steep so that relatively large changes of plate current are produced by small changes of grid potential.

In the accompanying drawings:

Figure 1 shows diagrammatically an arrangement of circuits representing a preferred form of my invention;

Figure 2 a modification thereof; and

Figure 3 a second modification in which the average current in each of a plurality of parallel connected tubes is regulated in order to maintain the same approximately constant in spite of variations of potential existing in the grid circuits of the tubes.

Figure 4 shows a third modification in which a plurality of parallel connected tubes have their plate circuits energized from a polyphase alternating current source, a regulating potential being impressed upon the grid circuits to minimize the low frequency variations in the average of all the plate currents.

Referring to Figure 1, an electron discharge device or audion 1, is shown, having a plate 2, grid 3, and filament 4. Connected to the grid 3 is a controlling circuit 5 adapted for connection to any source of actuating potential in any well known manner such as by the coupling 6, this source being of a magnitude suitable for the operation of the tube or audion. The plate or anode 2 is connected through a battery or suitable source of potential 7 through a useful load 8, which may include a current indicating device, to the filament through an aperiodic impedance consisting (as shown in Figure 1) of a resistance 9 in parallel with a condenser 10. Such an impedance is differently responsive to different frequencies yet substantially constant over a certain useful range of frequencies. Filament battery 11 supplies energy for the heating of the filament 4.

Assuming that a current is flowing from the plate 2 to the filament 4 through the tube, if by means of the grid circuit 5 a difference of potential is established between the grid and filament making the grid more positive than before, a much larger current will flow from the filament 4 to the plate 2 through the external circuit. This increased current flow will in turn cause an increased drop of potential through the resistance 9 and a corresponding change in the value of the charge in the condenser 10. After the charge in the condenser 10 has passed the

transitory state and becomes constant, the drop of potential through the resistance 9, being in the grid filament circuit, will act in opposition to the actuating potential previously impressed upon the circuit 5 so that the change in the anode or plate current is substantially less than would have been the case if the grid circuit 5 were not connected to the external plate circuit at 12 so as to be susceptible to the drop of potential through the impedance composed of resistance 9 and condenser 10. It will therefore be seen that variations in the plate current flowing in the external circuit superimposes upon the grid a regulating potential opposite in sign to that of the actuating potential imposed upon the grid from the source 6. If, as in normal operation, a high frequency actuating potential is imposed upon the grid circuit from the source 6, corresponding variations in the anode or plate current will be produced, the same flowing through the external circuit. These variations of plate current will pass through the condenser 10 readily, only the average or direct component of the plate current being compelled to pass through the resistance 9. As a result of this, variations of plate current will be but little modified by the drop of potential through the impedance consisting of resistance 9, capacity 10, and such stray or distributed capacity as is inherent in the apparatus, while at the same time any gradual changes in the average value of plate current will introduce a corresponding potential drop through the resistance 9, and impress upon the grid circuit a regulating potential which will tend to prevent this change. This arrangement of circuits thereby tends to keep an average constant plate current with but little effect upon any high frequency current flowing in the plate circuit. The circuit just described is of course adapted for reception, as well as the production of high frequency oscillations.

The modification shown in Figure 2 consists of the same circuit arrangement as that described in connection with Figure 1 with the exception that a slightly different form of impedance is disclosed. The impedance in this case consists of resistance or resistances 9 and inductance 13 in parallel with the condenser 10. By such construction this impedance may be made resonant to certain definite frequencies and the regulating potential impressed upon the grid circuit will have a maximum value with respect to the plate current flowing at certain desired frequencies. The impedance may be designed to have either a maximum or a minimum value for any given range of frequencies. The effectiveness of an impedance used in this circuit arrangement for regulating the anode or plate current does not depend upon its absolute value but rather upon its value compared to the internal impedance of the tube. While not limiting myself to any specific values of impedance 9 and 10, to be used by way of example it is stated that very satisfactory results were obtained where the resistance 9 was composed of slightly inductive resistance unit having an impedance of 1000 ohms, the condenser 10 having also an impedance value of about 1000 ohms and the internal impedance of the plate circuit was in the order of 100,000 ohms. The loop thus formed is aperiodic, i. e., its ratio of resistance to inductance and capacity inhibits oscillations. Since the resistive impedance is substantially independent of frequency and the inductive impedance is small, the capacitive impedance determines its action upon currents of different frequencies.

In some instances it has been desirable to control the plate current by the insertion of an impedance between points 13 and 14 in the plate circuit as shown in Figures 1 and 2. Such regulation demands the use of an impedance which tends to cut down the average value of plate current. By making use of circuits such as disclosed in Figures 1 and 2, however, the use of a much smaller impedance located as shown secures the desired regulation. The relationship existent between the values of the impedance shown in these figures and the fictitious impedance located between points 13 and 14 in the plate circuit which it replaces is substantially $(\mu+1)Z$, in which Z is the actual value of the impedance used and μ is the amplification constant of the tube when the grid is operated with but a negligible direct component in the grid current.

Figure 3 discloses a modification in which regulating potentials are impressed upon the grid circuits of a plurality of tubes in parallel for the purpose of obtaining a definite division of load between the tubes and at the same time appreciably preventing variation in the average value of plate current. In this circuit arrangement, the filaments 20 and 21 are heated by means of alternating current, although this is of course not a necessary requirement for the application of the present invention, the heating current being obtained from a transformer 21^a having separate secondaries 22 and 23 for the tubes. Choke coils 24 and 25 are connected across the terminals of the filaments 20 and 21 and have central taps leading therefrom through resistances 26 and 27 respectively to the plate circuit 28, 29, 30, 31, 32 and 33. Condensers 34 and 35 cooperate respectively with the impedances 26 and 27 in substantially the same manner as resistance 9 and capacity 10 in Figure 1 to impose upon the grid circuit 34 and 35 regulating potentials in accordance with the voltage drop existent in the external circuits between filaments 20

and 21 and the point 34 in the plate circuit. In each of the tubes there is therefore a tendency to hold an average definite value of anode current and there is thus a tendency towards a definite division of load between the tubes. It is further obvious that this arrangement may be applied to any number of tubes in parallel.

The modification shown in Figure 4 discloses the present invention as applied to a plurality of tubes in parallel in which the plate circuits are energized from an alternating current source. In this figure the tubes 1 have their filaments excited in any suitable manner as by batteries 11, the anodes of the tubes being connected respectively by means of circuits 36, 37 and 38 to the secondaries 39, 40 and 41 of low frequency transformers. The primaries of these transformers 42, 43, and 44 are connected to a three phase alternating current source. Instead of using separate transformers a three phase transformer of any suitable type might be employed. It is also feasible to employ either two phase or single phase current to provide for the excitation of the plate circuit, the single phase current being applied either directly to the primaries of the three transformers, or being connected thereto thru any well-known type of a phase splitting device so that the phases in the secondaries of the transformers will be suitably displaced one from the other.

The other ends of the secondary windings are connected to a common conductor at the point 45, a circuit leading from this point thru the regulating impedance 9, 10, 13^a to a common point 47 to which point the circuit branches to the three filaments of the tubes. The grid circuits 48, 49 and 50 lead to a common point 51 which is connected to the common plate circuit at 46, a suitable source of controlling or actuating potential being introduced in the common grid circuit by the coupling 6. As here shown the coupling 6 is adapted to energize the common portion of the grid circuits, but the actuating potential might also be impressed separately upon the separate grid circuits at points between the common point of connection 51 and the grids. Condensers 52, 53, and 54 are placed in parallel with the secondaries of the low frequency transformers in the plate or anode circuits in order to permit the high frequency pulsations to flow in the anode circuits without interference. From the description of the circuits already given in connection with Figure 1, it will be evident that the impedance 9, 10, 13^a imposes upon the grid circuits of the tubes, a regulating potential the tendency of which is to prevent variations in the plate current. In the arrangement of the circuits shown in connection with Figure 4 the resultant variation of the plate current is primarily much reduced when three phase current is utilized for the excitation of the plate circuits, the overlapping of the phases producing a resultant effect which is that of a varying direct current. By utilizing applicant's method of applying a regulating potential to the grid circuits the varying flow of current in the plate circuits is still further minimized, and a tendency towards a smooth resultant of the plate current is obtained.

The particular embodiments of my invention herein disclosed are of course susceptible to considerable variation without departing from the spirit thereof, and it is to be understood that many changes might be made by those skilled in the art within the scope of the invention as defined within the appended claims.

What I claim is:

1. The combination with an electron discharge device having a cathode, an anode, and a grid, of an external circuit connecting the cathode and grid and having therein means to impress upon said grid an actuating potential from an external source, a second external circuit connecting said cathode and anode and including an indicating device and having a portion in common with said first circuit, and an aperiodic loop circuit in series with the common portion of said circuits whereby low frequency variations in the anode current are opposed.

2. The combination with an electron discharge device having a cathode, an anode, and a grid, of an external circuit connecting the cathode and grid and having therein means to impress upon said grid an actuating potential from an external source, a second external circuit connecting said cathode and anode and including an indicating device and having a portion in common with said first circuit, and an aperiodic loop circuit comprising two branches in series with the common portion of said circuits, one of said branches containing inductive reactance and ohmic resistance and the other branch containing capacitive reactance, whereby said loop circuit is more actively operative at a certain frequency or frequencies than at other frequencies whereby low frequency variations in the anode current are opposed.

3. The combination with an electron discharge device having a cathode, an anode and a grid, of an external circuit connecting the cathode and grid and having intercalated means to impress upon said grid an actuating potential, a second external circuit connecting said cathode and anode and having a portion in common with said first external circuit, and an aperiodic loop in series in the common portion of said circuits to oppose variation of the anode current.

4. The combination with an electron dis-

charge device having at cathode, an anode and a grid, of an external circuit connecting the cathode and the grid and having intercalated therein means for impressing an actuating potential upon said grid, a second external circuit connecting said cathode and anode, said external circuits having a common portion, and means in said common portion whose impedance varies inversely with the frequency to oppose low frequency variations in the anode current or potential.

5. The combination with an electron discharge device having a cathode, an anode and a grid, of an external circuit connecting the cathode and the grid and having intercalated therein means for impressing an actuating potential upon said grid, a second external circuit connecting said cathode and anode, said external circuits having a common portion, and means controlled by the anode current in said common portion whose impedance varies inversely with the frequency to oppose low frequency variation in the anode current.

6. The combination with an electron discharge device having a cathode, an anode and a grid, of an external circuit connecting the cathode and grid and having intercalated therein means for impressing upon said grid an actuating potential from an external source, a second external circuit connecting said cathode and anode, a common portion of said circuits having two branches constituting a series loop circuit, and a resistance and a capacitance respectively in said branches, said loop circuit serving to oppose variations in the anode current or potential.

7. The combination with a circuit embodying a plurality of electron discharge devices in parallel, each having a cathode, an anode, and a grid, of grid circuits connecting each grid to the corresponding cathode, anode circuits connecting each anode to the corresponding cathode, said anode circuits having a common conductor, a source of anode current in said conductor, a portion of each anode circuit being common to the grid circuit of the corresponding electron discharge device, and means in said common portion for opposing changes in the anode current of that particular device.

8. The combination with a circuit embodying a plurality of electron discharge devices in parallel, each having a cathode, an anode, and a grid, of grid circuits connecting each grid with the corresponding cathode, anode circuits connecting each anode with the corresponding cathode, said anode circuits having a common conductor, a source of anode current in said common conductor, a portion of each anode circuit being common to the grid circuit of the corresponding electron discharge device, and means in said common portion for opposing changes in the anode current of that particular device, said means being more actively operative at a certain frequency or frequencies than at other frequencies.

9. The combination with an electron discharge device having a cathode, an anode, and a grid, of an external circuit including a source of electricity to energize said cathode and connected thereto, an inductance connected in shunt across said cathode, two condensers in series connected in shunt across said cathode, a resistance connected between the midpoint of said inductance and the midpoint of said condensers, an external conductor connecting the grid with the midpoint of said condensers, and a second external conductor connecting the anode with the midpoint of said condensers.

10. The combination with a circuit employing a plurality of electron discharge devices in parallel, each having a cathode, an anode, and a grid, of an anode circuit connected to all of said anodes, a source of anode current in said anode circuit, and means for a substantially equal distribution of load between said devices comprising an impedance of relatively high value for a constant or slowly varying current inserted in the anode circuit of each device at a point common to the grid circuit of said device so that the voltage drop due to the anode current flowing through said impedance will be impressed upon the grid circuit of that tube.

11. In a circuit including a vacuum tube comprising a cathode, a grid and an anode, connections for energizing the said elements, a portion of said connections being common, means in said common portion for opposing oscillations due to electrical interaction comprising a loop circuit containing resistance and capacity, the reactance of the former being greatly in excess of that of the latter at operating frequencies.

In testimony whereof, I affix my signature.

GORDON DUDLEY ROBINSON.