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ELECTRON DISCHARGE SYSTEM

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Fig. 1.

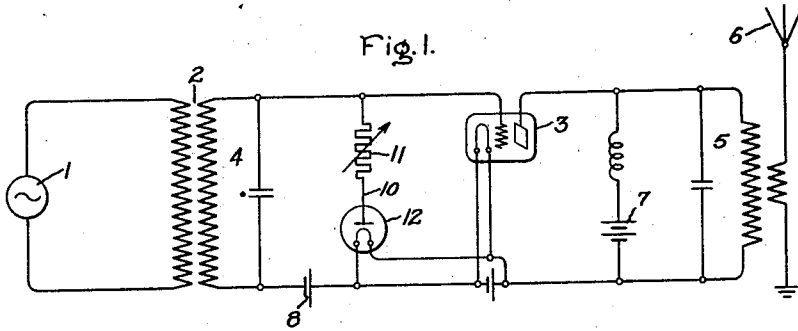


Fig. 2.

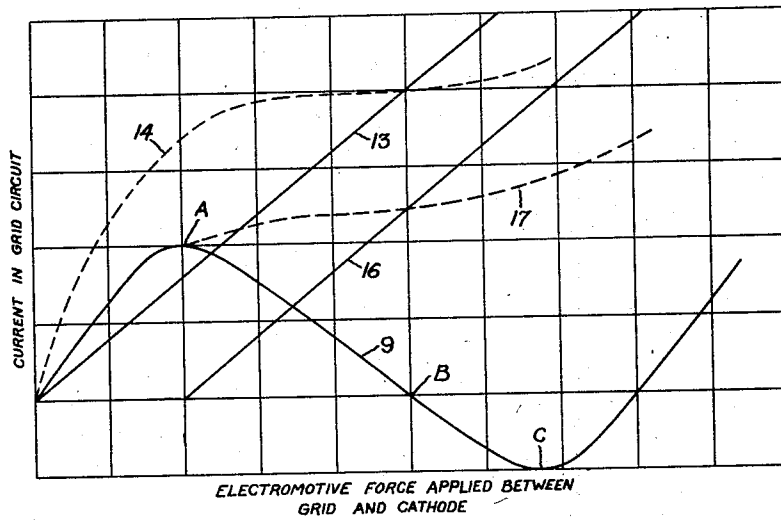


Fig. 3.

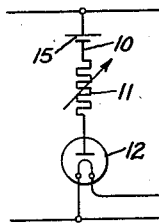
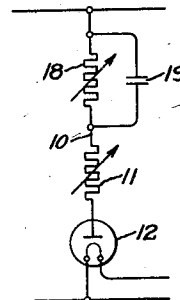


Fig. 4.



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UNITED STATES PATENT OFFICE

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ELECTRON DISCHARGE SYSTEM

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My invention relates to systems employing electron discharge devices, and it has among its objects to provide a method and means for eliminating undesired effects in the circuits of electron discharge devices caused by emission of secondary electrons from the grid to the anode.

More particularly it has for its purpose to provide means for preventing the production of undesired oscillations in the circuits associated with the grid and cathode due to negative resistance in the grid circuit of the discharge device resulting from the emission of secondary electrons from the grid.

Another object of the invention is to provide means in the circuit whereby the resistance of the circuit looking toward the discharge device from those portions of the circuits which are capable of oscillating at undesired frequencies, is positive, constant, or insufficiently negative to support oscillations in the circuit. In accordance with the invention this resistance may be varied as desired over a considerable portion of the range of grid voltage variations over which negative resistance within the discharge device occurs.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which Fig. 1 represents an electron discharge circuit arrangement employing my invention; Fig. 2 represents certain of the characteristics thereof, and Figs. 3 and 4 represent modifications of my invention as shown in Fig. 1.

Referring to Fig. 1 of the drawings I have shown a conventional electron discharge amplifier circuit in which oscillations to be amplified are supplied from a source 1 through an input transformer 2 to the grid of an electron discharge device 3. Both the grid and the anode circuits of the discharge device 3 are tuned to the operating frequency as indi-

cated by the tuned circuits 4 and 5. A load circuit, represented by an antenna 6, is coupled with the oscillatory circuit 5 to receive the amplified oscillations. A suitable positive potential is applied to the anode of the discharge device 3 by means of a unidirectional source of electromotive force 7 and, similarly, a suitable bias voltage is applied to the grid by means of the source 8.

It frequently occurs in the operation of electron discharge devices and, particularly, discharge devices constructed for operation at high voltages and in which the grid is operated at positive potential with respect to the cathode during a portion of the cycle of oscillations to be amplified that bombardment of the grid with electrons from the cathode causes an emission of secondary electrons from the grid, these secondary electrons being attracted away by the more positive anode. The number of secondary electrons emitted from the grid is dependent upon the velocity with which primary electrons hit the grid, which in turn is dependent upon the voltage applied between the grid and cathode. As the grid potential increases in a positive direction over a certain range thereof, the number of electrons emitted from the grid increases and may become equal or greater than the number of primary electrons which hit the grid, thereby imparting to the space between the grid and cathode a negative resistance characteristic over a portion of the range of grid voltage variation.

This characteristic of the discharge device is indicated by the curve 9 in Fig. 2. This curve represents the relation between the current flowing in the grid circuit and the electromotive force applied between the grid and cathode. It will be seen that as the grid voltage is increased from zero the grid current likewise increases to a point indicated at A on the curve. At this point the velocity of electrons between the cathode and grid becomes sufficiently great to cause a certain number of secondary electrons to be driven off from the grid due to bombardment of the grid by the primary electrons from the cathode. These electrons are attracted away from the grid by the more positive anode and rep-

resent a flow of current in the grid circuit opposite in direction to that represented by the primary electrons. Thus, the total current flowing in the grid circuit then starts to decrease and as the grid becomes more positive the emission of secondary electrons continues to increase until their number is equal to the number of primary electrons which reach the grid, at which time the current in the grid circuit is zero, as indicated by the point B on the curve 9. As the grid becomes still more positive the number of secondary electrons still increase until a point is reached, as represented by the point C, at which the anode is insufficiently positive to attract all of the secondary electrons which are emitted from the grid. These electrons which are not attracted to the anode thus fall back into the grid. Thus from this point on as the grid potential is increased the current in the grid circuit continues to increase, as shown by the portion of the curve 9 at the right of the point C.

It will be seen that over that portion of the range of grid voltage variation between the points indicated at A and C on the curve 9 there is a decrease in current as the grid voltage increases or, in other words, the space between the grid and cathode has negative resistance.

Due to this negative resistance, as is well known in the art, oscillations are likely to be set up in the circuits which are associated with the grid. These oscillations may appear in any portion of the circuit which is capable of resonance at a parasitic frequency as in the leads extending to the grid bias voltage of a practical installation, or in the tuned circuit 4, or elsewhere in the circuit. Among other undesirable effects which are likely to be produced by oscillations of this kind is that of parasitic modulation of the oscillations amplified by the device 3.

In accordance with the present invention the undesired effects of the negative resistance of the discharge device are obviated by connecting across the grid circuit a path indicated at 10 in Fig. 1 having positive resistance. This path, as shown in the figure, comprises a resistance 11 and an electron discharge device 12. The discharge device 12 is of any suitable two-element type having its anode connected through the resistance 11 to the grid of the discharge device 3, and its cathode connected to the cathode of the discharge device 3. The current flowing in the path 10 varies directly as the electromotive force applied to the grid of the discharge device 3. This current may be represented by the curve 13 of Fig. 2. The total current flowing in the grid circuit of the discharge device is then the sum of the currents flowing in the path 10 and that flowing from the grid of the discharge device 3. In other words, it is the sum of the currents represented by

curves 9 and 13 of Fig. 2. This total current is indicated by the curve 14 of Fig. 2.

It will be seen that this curve represents a positive resistance throughout the entire length thereof; that is, the resistance of the two parallel paths comprising the path 10 and the path between the grid and cathode of the discharge device 3 is positive throughout the entire range of voltage variations.

The path 10 may be connected across the grid circuit at a point sufficiently close to the discharge device 3 to preclude the possibility of the currents of parasitic frequencies being set up in the conductor extending from the grid of the discharge device 3 to the branch circuit 10. Since the resistance of the circuit, as measured at all points to the left of the branch 10, is positive, the effect of negative resistance in the discharge device 3 is obviated.

Due to the damping of the grid circuit, however, it is unnecessary to entirely obviate the negative resistance so long as it is maintained at a value which is insufficiently negative to overcome the damping effect of the circuit, and thus cause oscillations to be produced. Thus, if desired, the slope of the curve represented at 13 of Fig. 2 may be varied by varying the resistance 11 included in the branch circuit. In this way the slope of the curve 14 over that range of variations in grid electromotive force in which negative resistance is likely to occur, may be varied, and, if desired, may be caused to represent a negative resistance within a range, as indicated above, which may be tolerated. If desired this resistance may be made substantially constant over a considerable portion of the range in which negative resistance in device 3 occurs.

A considerable economy in the energy expended in the grid circuit, however, may be effected by biasing the anode of the discharge device 12 negatively with respect to the cathode. This modification of the invention is shown in Fig. 3 in which a source of electromotive force 15 is connected in the branch circuit 10 and so polarized that the anode of the discharge device 12 is negative with respect to the cathode. As thus arranged, it is necessary that a greater positive potential be applied to the grid of the discharge device 3 before current starts to flow in the branch circuit 10. The source of potential 15 may be so adjusted that the flow of current in the branch circuit 10 begins approximately at the same value of grid electromotive force at which the emission of secondary electrons begins, this current increasing with respect to grid voltage as represented by the curve 16 of Fig. 2. The total current flowing in the grid circuit may then be represented by the curve 17. This curve represents a very considerable reduction in the amount of current flowing in the grid circuit, and, at the same

time, indicates that the effect of the negative resistance of the discharge device 3 is obviated. The slope of the curve 16 may of course be varied as before by variation of resistance 11 thereby to control the slope of the curve 17 over which negative resistance is likely to occur.

In Fig. 4 I have represented a further modification of the invention in which the source of biasing potential 15 is replaced by a resistance 18 shunted by a condenser 19. The condenser 19, after the first few cycles of applied electromotive force of the source 1 to the grid of discharge device 3 assumes a fairly definite charge causing the anode of the discharge device 12 to become negative with respect to the cathode. This charge may, of course, be varied by varying the resistance 18 and, hence, by varying the resistance 18 the value of grid electromotive force at which current starts to flow in the branch circuit 10 may be varied. Thus curve 16 may be shifted, either to the right or to the left, by variation of the resistance 18. The slope of the curve 16 may of course be varied by varying the resistance 11.

The use of the asymmetrically conducting discharge device 12 in the path 10 is particularly advantageous not only in that the point at which the flow of current begins may be readily adjusted but also in that it prevents the flow of current therethrough and the consequent waste of energy in the grid circuit during the portion of the alternating current cycle when the anode is negative as would be the case were the path 12 conducting in both directions. Further the resistance of this device employed as described may be sufficiently high to prevent objectionable distortion of the oscillations supplied to the grid due to energy shunted through the asymmetrically conducting discharge device.

While I have shown in the drawings a conventional amplifier circuit employing a three-element electron discharge device, it will of course, be understood that I contemplate the use of my invention in connection with discharge devices having any greater number of electrodes in which any of the electrodes is sufficiently positive to produce a negative resistance between the grid and cathode, and, in fact, in connection with multi-electrode discharge devices generally.

While I have shown particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto since many modifications, both in the circuit arrangement and in the instrumentalities employed, may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of operating a three-ele-

ment electron discharge device having a grid and cathode, and conductors connected thereto, said conductors being connected in circuit relation, and in which sufficient emission of secondary electrons from the grid may occur to produce a negative resistance between the grid and cathode which includes causing sufficient unidirectional current varying directly as the voltage between said conductors to flow from the cathode conductor to the grid conductor and through said external circuit to cause the current in the external circuit to remain approximately constant over a range of voltage variations between said conductors.

2. In combination, an electron discharge device having a grid, a cathode and a third electrode, a circuit connected between the grid and cathode including a source of variable electromotive force, a source of electromotive force connected between the third electrode and cathode, the relative values of said electromotive forces being such that the curve representing the relation between the current flowing in the grid circuit and the electromotive force between the grid and cathode has a negative slope over a portion of the range of variations of grid electromotive force, and means for causing additional unidirectional current to flow in the circuit connected to the grid and cathode, said means being such that the curve expressing the relation between the electromotive force of said grid and said additional current has a slope substantially equal and opposite to the negative slope of said first-mentioned curve over the same portion of the range of variations of grid electromotive force.

3. The combination, in an electron discharge amplifier having an anode, a cathode and a grid, of an input circuit including a source of oscillations to be amplified connected between the grid and cathode, an output circuit for amplified oscillations connected to the anode and cathode, means for impressing a positive potential on said anode, the amplitude of said oscillations to be amplified and said anode potential being in relation to cause a negative resistance between the grid and cathode over a portion of the cycle of said oscillations, and means to overcome the effect of said negative resistance produced during said emission of secondary electrons, comprising an electron discharge device having an anode connected to said grid and a cathode connected to the cathode of said amplifier.

4. The combination, in an electron discharge amplifier having an anode, a cathode, and a grid, of an input circuit including a source of oscillations to be amplified connected between the grid and cathode, an output circuit for amplified oscillations connected to the anode and cathode, means for impress-

ing a positive potential on said anode, the amplitude of said oscillations to be amplified and said anode potential being in relation to cause a negative resistance between the grid and cathode over a portion of the cycle of said oscillations to be amplified, a conducting path between the grid and cathode including an electron discharge device and a source of potential, the potential of said source having such a value that substantially no current flows in said path except during those portions of the cycle of said oscillations when the potential on the grid is sufficiently positive to cause the grid to have negative resistance.

5. In combination, an electron discharge amplifier, having a grid and cathode, a circuit conductive to direct currents and including a source of oscillations connected to the grid and cathode whereby the grid is caused to become alternately positive and negative with respect to the cathode, and a path connected across said circuit including an asymmetrically conducting discharge device and a source of biasing electromotive force, said electromotive force being such that current flows in said discharge device only during that portion of alternate half cycles of said oscillations when the potential on the grid is sufficiently positive to cause the grid to have negative resistance.

6. The combination, in an electron discharge amplifier having an anode, a cathode and a grid, of an input circuit including a source of oscillations to be amplified connected between the grid and cathode, an output circuit for amplified oscillations connected to the anode and cathode, means for impressing a positive potential on said anode, the amplitude of said oscillations to be amplified and said anode potential being so related as to cause a negative resistance between the grid and cathode over a portion of the cycle of said oscillations, a path having positive resistance connected across said circuit, said path being conductive only during that portion of the cycle of said oscillations when the grid is sufficiently positive with respect to the cathode to cause the emission of secondary electrons therefrom, and means for varying the value of grid electromotive force at which said path becomes conducting.

7. In combination, an electron discharge device having an anode, a cathode and a grid, a circuit between the grid and cathode including a source of oscillations to be amplified, a circuit for the amplified oscillations connected between the anode and cathode, means for impressing a positive potential on the anode of such value with respect to the amplitude of said oscillations that negative resistance is produced between the grid and cathode during a portion of the positive half cycle of said oscillations, an asymmetrically conducting discharge device having a cathode

connected to said first mentioned cathode and an anode connected to said grid, the combined resistance of said asymmetrically conducting discharge device and the negative resistance between said grid and cathode being insufficiently negative during said portions of the positive half cycle of said oscillations to be amplified when said negative resistance is produced to cause the production of undesired oscillations in the grid circuit.

8. In combination, an electron discharge device having an anode, a cathode and a grid, a circuit between the grid and cathode including a source of oscillations to be amplified, a path between said grid and cathode including a discharge device conducting only when the grid is positive, means for impressing a positive potential on the anode the amplitude of said oscillations being sufficiently great to cause a negative resistance between the grid and cathode during a portion of the positive half cycle of said oscillations and the combined resistance of said path and said negative resistance being insufficiently negative during said portion of the positive half cycle to prevent the production of undesired oscillations in the grid circuit and the resistance of said path being sufficiently high substantially to prevent distortion of the positive half cycle of said oscillations due to energy shunted through said path.

9. In combination, an electron discharge device having an anode, a cathode and a grid, a circuit between the grid and cathode including a source of oscillations to be amplified, a circuit for the amplified oscillations connected between the anode and cathode, means for impressing a positive potential on the anode of such value with respect to the amplitude of said oscillations that negative resistance is produced between the grid and cathode during a portion of the positive half cycle of said oscillations, an asymmetrically conducting discharge device having a cathode connected to said first mentioned cathode and an anode connected to said grid, a source of electromotive force included in circuit with said asymmetrically conducting discharge device of such a value that current flows in said discharge device only when the potential on said grid is sufficiently positive to cause said negative resistance to occur between said grid and cathode, and a resistance in series with said asymmetrically conducting discharge device of such a value that the total change in current in said circuit between said grid and cathode is small with respect to the change in grid voltage over that portion of the half cycle where said negative resistance occurs.

10. In combination, an electron discharge device having an anode, a cathode and a grid, a circuit between the grid and cathode including a source of oscillations to be amplified, a circuit for the amplified oscillations

connected between the anode and cathode, means for impressing a positive potential on the anode of such value with respect to the amplitude of said oscillations that negative resistance is produced between the grid and cathode during a portion of the positive half cycle of said oscillations, an asymmetrically conducting discharge device having a cathode connected to said first mentioned cathode and an anode connected to said grid, means connected in circuit with said asymmetrically conducting discharge device for producing from the current flowing through said asymmetrically conducting discharge device a continuous unidirectional electromotive force of such value as to prevent the flow of current through said asymmetrically conducting discharge device except when said grid is sufficiently positive with respect to the cathode of said first mentioned discharge device to produce said negative resistance.

11. In combination, an electron discharge device having an anode, a cathode and a grid, a circuit between the grid and cathode including a source of oscillations to be amplified, a circuit for the amplified oscillations connected between the anode and cathode, means for impressing a positive potential on said anode of such value with respect to the amplitude of said oscillations to be amplified that a negative resistance is produced between the grid and cathode during a portion of the positive half cycle of said oscillations, an asymmetrically conducting discharge device and resistance connected in series between said grid and cathode, and a condenser connected in shunt with said resistance whereby an electromotive force is maintained on said resistance of such magnitude as to prevent the flow of current through said discharge device until said grid is sufficiently positive with respect to the cathode to cause said negative resistance between the grid and cathode.

In witness whereof, I have hereunto set my hand this 27th day of March, 1930.

MARCUS A. ACHESON.