Oct. 2, 1934. P. T. FARNSWORTH 1,975,143

THERMIONIC VACUUM TUBE

Filed July 22, 1931

Fig. 1.

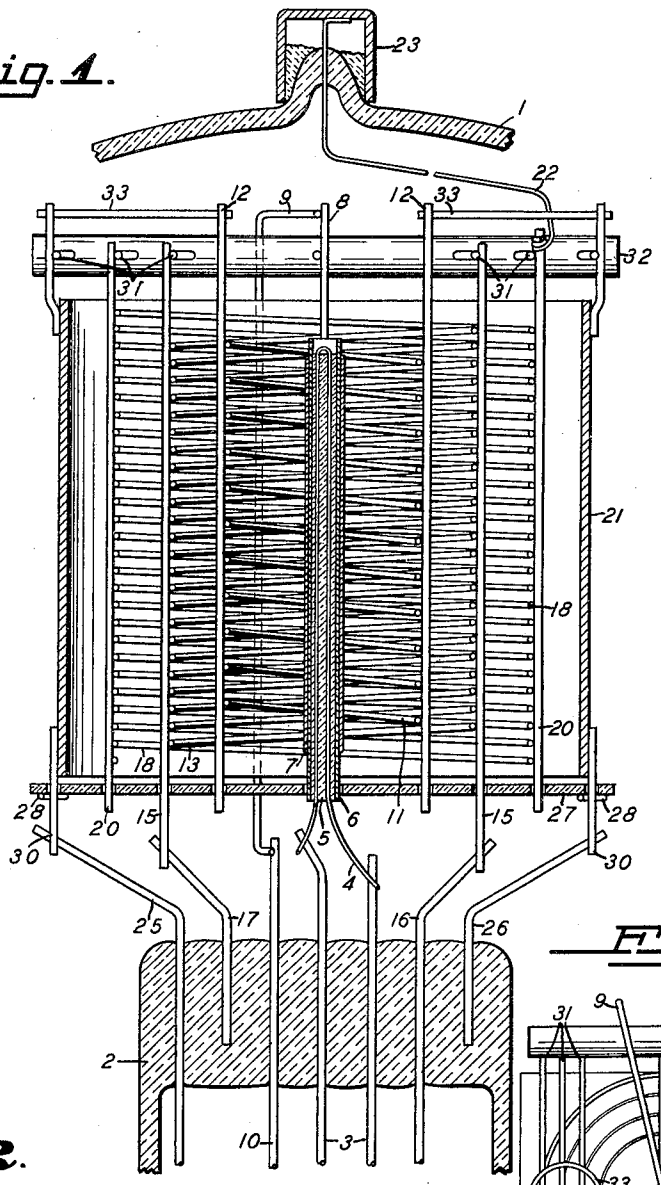


Fig. 3.

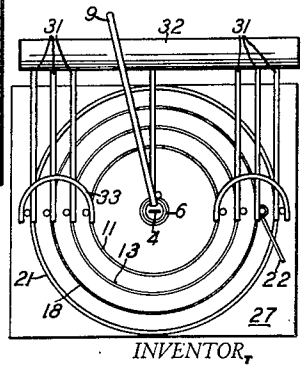
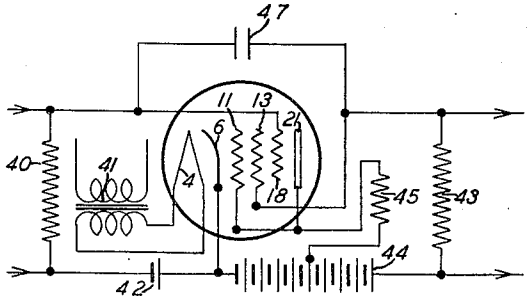


Fig. 2.



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THERMIONIC VACUUM TUBE

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Application July 22, 1931, Serial No. 552,339

4 Claims. (Cl. 250—27)

This invention relates to thermionic vacuum tubes for amplifying electrical signals, and particularly to a vacuum tube wherein the variations in output potential are in phase with the variations in input potential, instead of being 180° out of phase as is the case in vacuum tubes of the ordinary type.

Among the objects of my invention are: To provide an amplifier tube capable of neutralizing the admittance to its input circuit, as described in my copending application, Serial No. 346,078, filed March 11, 1928, for patent on an Admittance neutralizing amplifier; to provide a tube of the character descrbed which is commercially reproducible in large quantities; to provide a tube which is stable in operation and is not critical as to plate or grid biases; and to provide a receiving tube having a relatively high value of transductance or "mutual conductance".

Other objects of this 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 the invention herein described, as various forms may be adopted within the scope of the claims.

Referring to the drawing:

Figure 1 is an axial sectional view on an enlarged scale showing the elements of a small portion of the envelope of a tube embodying my invention.

Figure 2 is a schematic wiring diagram showing the method of utilizing the tube of Figure 1 in an admittance-neutralized circuit.

Figure 3 is a plan view, on a smaller scale than Figure 1, of the elements of the tube illustrated in Figure 1.

In my above identified copending application it is pointed out that a vacuum tube whose output potential varies in the same sense as its input potential is capable of neutralizing capacitances and other admittances in its input circuit. The tubes shown in that application depend for their action upon the secondary emission of electrons, and for this reason it is difficult to produce them, in commercial quantities, having uniform operating characteristics, it frequently being necessary to test a large number of tubes before a complete set having substantially uniform characteristics can be found. In the present invention, I provide a tube whose output characteristics are satisfactory for the purpose mentioned, but which does not rely upon secondary emission for its operation.

Broadly considered, the tube of the present invention comprises a thermionic cathode, a plate, a control electrode between cathode and plate, and an output electrode of foraminated or grid form between the control electrode and the cathode. There is preferably added a fifth electrode, also in the form of a grid, between the output electrode and the cathode, which is connected to the anode. Variations in the potential of the control grid change the distribution of the space charge between said grid and the cathode, and hence the potential distribution within this space. When the grid swings positive, the electrons between the grid and the cathode are accelerated, and passed through the output electrode and the control grid to the plate. When the grid swings negative, however, this flow of electrons is slowed, the density of the space charge adjacent the output electrode increases, and the current to this electrode also increases. When this current is passed through a suitable output impedance, the resultant potential drop is in phase with the control electrode potential. When the inner grid is used, and this inner grid and plate are connected, through a resistance of relatively low value, to a positive potential which is less than the positive potential of the output electrode, variations of potential out of phase with the variations of control potential occur upon the inner grid. This grid, lying between the cathode and the output electrode, serves to redistribute the potential gradient in this region, accentuating the variations of space charge in the neighborhood of the output electrode and giving the latter a high positive transductance, as compared to the negative transductance of the usual vacuum tube.

Figure 1 shows in detail a preferred embodiment of a tube embodying these principles. The usual envelope of the tube is shown in fragmentary form, indicated by the reference character 1, the portion of the stem or press of the tube is indicated by the reference character 2. Passing through the press is a pair of leads 3 which are connected to the heating element 4 of a heater-type cathode. The element 4 passes through a pair of parallel holes in a cylinder 5 of insulating material, the cylinder being surrounded by a metallic thimble 6, upon which is deposited a coating 7 which is preferably formed of alkaline earth oxide or other material adapted for the ready emission of thermo electrons. The conducting thimble 6 is connected through wires 8 and 9 to a cathode lead 10 passing out through the stem.

The cathode is surrounded by a grid 11 comprising a spiral of relatively large pitch and

formed of fine wire, and welded or otherwise secured to vertical support wires 12. The spacing between this inner grid and the cathode is preferably considerably greater than the spacing of the ordinary space-charge grid in the usual tetrodes or pentodes.

Surrounding the inner gride 11 is an intermediate grid 13, the openings through which are much smaller than those through the grid 11, this being accomplished in the present instance by winding the grid coil with a smaller pitch. The grid coil 13 is carried by a pair of vertical supports 15, one of which connects to an output lead 16, while the other connects to a dummy support 17 held by the press 2. This second grid constitutes the output electrode of the tube.

A third grid 18, of similar construction to the intermediate grid, and supported on vertical wires 20, surrounds the output electrode and is in turn surrounded by a plate 21. The grid 18 preferably connects through a lead 22 with a contact cap 23 on a tip of the tube. The plate 21 connects to a lead 25 sealed through the stem, and to a supporting dummy 26.

In order to add stability to the structure, the vertical supports of the various grids and the plates preferably pass through a sheet of mica 27, which is held just below the tube elements by small wire clips 28 welded to the plate-support wires 30. The upper ends of the vertical support-wires are secured to a series of horizontal wires 31, which are sealed to a glass rod 32 arranged above and a little to one side of the plate structure.

The position of the various elements is capable of a considerable degree of variation in order to impart various characteristics to the tube, as is also the shape and nature of the various grid structures. The most convenient structure is, of course, the concentric cylindrical one which has generally been adopted by modern tube manufacturers, and hence the terms "inner" and "outer" have been adopted to describe the grids, but it is to be understood that parallel grid structures and other well known modifications are possible, so that the term "inner" as here used indicates merely the grid closer to the cathode, while "outer" indicates a grid more remote from the cathode.

The position of the output electrode 13 between the inner and outer grids may be varied to a considerable degree, but its preferred position varies from midway between the inner and outer grids (as shown) to a position closely adjacent the outer grid and more widely spaced from the inner one.

The inner grid 11 and its plate 21 are directly connected within the tube by wires 33.

The connections used for this tube are shown in schematic form in Figure 2. The input or control potential is applied across a suitable resistor 40, as is shown by the input arrows. A transformer 41, whose primary connects to a suitable commercial source of supply is connected to the heater and raises the cathode 6 to emitting temperature.

The resistor 40 is connected between the cathode 6 and the control grid 18, a C-battery 42 preferably being provided to maintain the control grid negative. The output grid 13 is connected through a resistor 43 to a battery or other potential source 44, whose negative end connects to the cathode. The plate 21 and inner grid 11 connect through a resistor 45, of the order of 2,000 ohms, to an intermediate point on the source 44.

In practice, the resistor 43 may be of the order of 50,000 ohms, the voltage applied to the plate and inner grid may be of the order of 85 volts, while the voltage of the source as applied to the output electrode 13 is of the order of 180 volts.

The potential drop across the resistor 40 is applied between the cathode 6 and the control grid 18 in the usual manner. Electrons from the cathode are accelerated first by the inner grid 11 and then by the output electrode 13, to a maximum velocity where they pass through the output electrode, a certain percentage of the electrons striking the output electrode and returning to the cathode via the output resistor 43. Between the electrode 13 and control grid 18 the electron stream is greatly decelerated, a certain percentage of them passing through the grid to reach the plate 21, this portion varying with the variations of grid potential. Owing to the resistor 45, these changes in current to the plate are accompanied by changes in the potential of the plate and the inner grid 11, these elements becoming more positive when the grid becomes negative, and vice versa.

When the grid 18 swings negative and the current to the plate is decreased, the concentration of the cloud of electrons surrounding the output grid 13 becomes greater, hence increasing the output current. This results in a greater voltage drop through the resistor 43, so that the output electrode swings negative in phase with the grid 18.

The effect as thus far described will take place even in the absence of the inner grid 11 and the resistor 45. Tubes have been made and operated in this manner, but their effectiveness is not as great as the tubes shown, wherein the following additional action takes place: As the grid 18 swings negative the grid 11 swings positive, increasing the flow of the electrons through the inner grid. Owing to the fine wire of the inner grid and its wide spacing, the total current to this grid is small, and the changes in this current with changes in control grid potential are negligible. These changes, such as they are, are in opposite phase to the changes in current to the plate itself and are over-ridden by the plate current changes.

The result of the increased flow through the inner grid is further to increase the space charge in the neighborhood of the output grid, greatly increasing the number of electrons finally arriving at the output grid and the total flow of current through the output circuit. In a tube constructed substantially as shown, the transductance between control grid and plate is of the order of 1,500 micromhos while the transductance between control grid and output electrode is of approximately the same value but of opposite sign. In the nomenclature which I have adopted, the transductance of the usual amplifying tube is considered as negative, since it leads to reversals in potential between control electrode and plate, while the transductance of the output electrode of the tube here described is considered as positive, since it leads to output potential variations of the same sign as the input potentials.

As has been pointed out in my above mentioned application, the capacitance in the input circuit of a tube of this character may be neutralized by a smaller capacitance 47 connected between the control grid and the output electrode.

The grid to output-electrode capacity of the present tube therefore serves to decrease the ef-

fective input capacity of the tube. There is, of course, also present a grid to plate capacity of the usual sign between the elements 18 and 21, but owing to the fact that the resistance 45 is relatively low, the changes in plate potential are also small as compared to the changes in potential of the output electrode. Therefore the additional input capacity due to this cause is small, and is entirely over-ridden by the effect of the capacity between electrodes 13 and 18, and that of the additional condenser 47.

I claim:

1. The method of operating a thermionic vacuum tube having a cathode, a plate, and at least three grids spaced between said cathode and plate to produce amplified potentials in phase with a control potential, which comprises applying said control potential to the outermost of said grids to vary the plate current, applying variations of potential caused by the plate current to the innermost of said grids, and utilizing the changes in current to the intermediate grid caused by the combined potential variations of the other grids to provide the desired amplified potential.

2. The method of operating a thermionic vacuum tube having a cathode, a plate, and at least three grids spaced between said cathode and plate to produce amplified potentials in phase with a control potential, which comprises applying a relatively high positive potential to the intermediate one of said grids, applying a lower positive potential to said plate and the innermost of said grids, applying said control potential to the outermost of said grids, and utilizing current variations to said intermediate grid to provide the desired amplified potential.

3. In combination, a thermionic tube having a cathode, a plate, and at least three grids spaced between said cathode and plate, an input circuit connected to the outermost of said grids, an output circuit including a source of positive potential connected to the intermediate one of said grids, and means for supplying a potential less positive than that of said intermediate grid to said plate and said innermost grid, whereby potential changes in said output circuit are in phase with the potential changes in said input circuit.

4. In combination, a thermionic tube comprising a cathode, a plate, an inner grid surrounding said cathode and connected to said plate, an output electrode foraminated to permit the passage of electrons therethrough, a control grid positioned between said output electrode and said plate, means for applying alternating current to said control electrode, means for supplying a positive potential to said output electrode, means for supplying a less positive potential to said plate and inner grid, and means for utilizing the changes in said output circuit due to the action of said alternating current.

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