June 10, 1941. A. L. SAMUEL 2,245,159

ELECTRON DISCHARGE APPARATUS

Filed June 3, 1939

FIG. 1

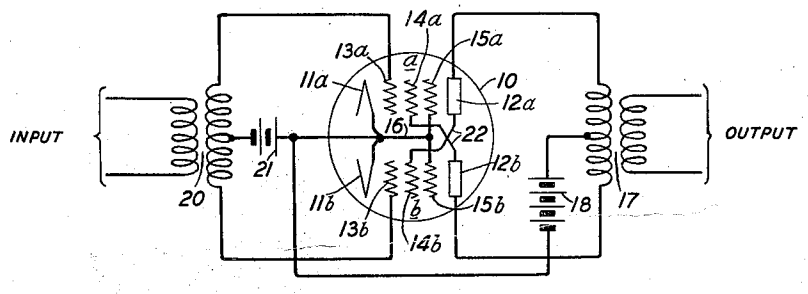


FIG. 2

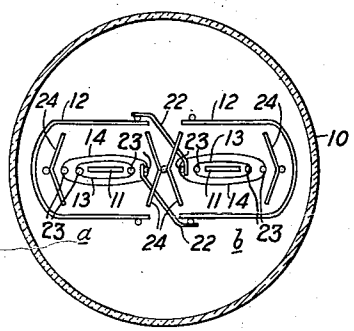


FIG. 3

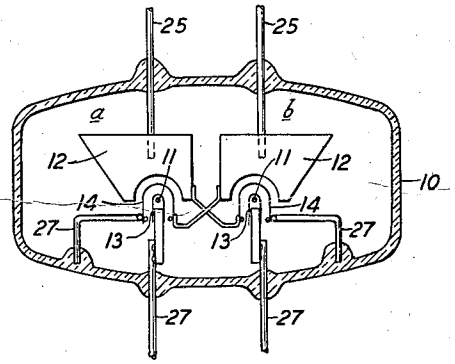
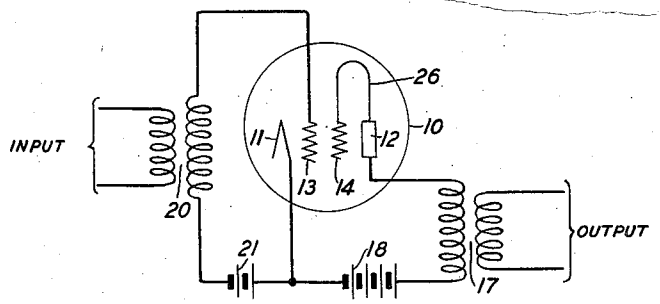


FIG. 4



INVENTOR
A.L.SAMUEL

BY Walter C. Kiesel

ATTORNEY

Patented June 10, 1941

2,245,159

UNITED STATES PATENT OFFICE

2,245,159

ELECTRON DISCHARGE APPARATUS

Arthur L. Samuel, Summit, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 3, 1939, Serial No. 277,143

6 Claims. (Cl. 179—171)

This invention relates to electron discharge apparatus and more particularly to such apparatus especially suitable for amplification of ultra high frequency signals, for example signals of frequencies corresponding to wave-lengths of one meter or less.

One object of this invention is to facilitate substantial neutralization of the control grid to anode capacitance in electron discharge devices.

Another object of this invention is to enable the attainment, in an electron discharge device, of a space current which is substantially independent of the alternating current component of the anode potential.

A further object of this invention is to simplify the electrical structure of multigrid electron discharge devices whereby certain of the leading-in conductors are eliminated and the inductances of connections between certain electrodes are substantially minimized.

Still further objects of this invention are to facilitate the attainment of stable operation of electron discharge devices and to simplify the design of amplifier circuits including such devices.

In one illustrative embodiment of this invention, electron discharge apparatus comprises a cathode, an anode, a control grid and a screen grid between the control grid and the anode.

In accordance with one feature of this invention, the screen grid is designed to have an amplification factor of substantially unity and means are provided for impressing upon the screen grid an alternating potential equal in magnitude and 180 degrees out of phase with the alternating potential appearing upon the anode by virtue of alternating potentials impressed upon the control grid.

In accordance with another feature of this invention, two screen grid electrode units are mounted within a single enclosing vessel and connected in push-pull relation, and the screen grid of each electrode unit is directly connected by a short connection of substantially negligible inductance to the anode of the other electrode unit.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a circuit diagram of a push-pull amplifier illustrative of one embodiment of this invention;

Fig. 2 is a top view partly in section of an electron discharge device constructed in accordance with this invention;

Fig. 3 is an end view partly in section of another electron discharge device constructed in accordance with this invention; and

Fig. 4 is a circuit diagram of an amplifier illustrative of another embodiment of this invention.

Referring now to the drawing, the amplifier shown in Fig. 1, which may be utilized for operation at ultra high frequencies, for example 300 megacycles or higher, comprises an electron discharge device including an evacuated enclosing vessel 10 housing a pair of identical multigrid electrode units *a* and *b*. Each of these units includes a cathode 11, which may be filamentary or of the indirectly heated equipotential type, an anode 12, a control grid 13 between the cathode and anode, and a screen grid 14 between the control grid and the anode. Each unit may include also a suppressor grid 15 dipsosed between the corresponding screen grid and anode and connected directly to the cathode as by a conductor 16. The electrodes of the units are identified in Fig. 1 by the appropriate numerals and letters *a* and *b* to facilitate discussion thereof hereinafter.

The two units may be connected in push-pull relation, the anodes 12 being connected to opposite ends of the primary winding of an output transformer 17 and maintained at a positive potential with respect to the cathodes 11, as by a battery 18, and the control grids 13 being connected to opposite ends of an input transformer 20 and suitably biased, as by a battery 21.

In accordance with one feature of this invention, each of the screen grids 14 is connected directly within the enclosing vessel to the anode 12 of the other unit by a short conductor 22 of substantially negligible inductance, whereby the screen grids are at the same direct current potential as the anodes and the alternating potential appearing upon each screen grid is of the same magnitude as, and 180 degrees out of phase with, the alternating potential appearing upon the anode of the same unit by virtue of signals impressed upon the grid. That is to say, because of the direct connection between the anode 12*b* and the screen grid 14*a*, the alternating potentials appearing upon these two electrodes will be of the same magnitude and in phase. Because of the push-pull relation of the units, the alternating potential appearing upon the screen grid 14*a* will be of the same magnitude as, and 180 degrees out of phase with, that upon the anode 12*a*. Similarly, the alternating potential appearing

upon the screen grid 14b is of the same magnitude as and 180 degrees out of phase with that upon the anode 12b.

The effective output current, of course, is the difference between the anode and screen grid currents. By varying the electrode parameters any desired output impedance, positive or negative, may be obtained.

In accordance with a feature of this invention, the screen grids 14 are constructed to have an amplification factor of substantially unity, the amplification factor being defined mathematically as the ratio

$$\frac{\partial E_p}{\partial E_g}$$

for zero change in the anode current, where E_p is the anode potential and E_g the screen grid potential. Preferably the screen grids are so constructed, as by aligning the wires thereof with those of the corresponding control grid, that the electron current thereto is very small.

In a device of such construction and connected as shown in Fig. 1, the space current will be substantially independent of the alternating current component of the anode potentials inasmuch as an increase in the potential of each anode is accompanied by a corresponding decrease in the potential of the screen grid of the same unit. Hence, a high impedance is obtained.

Inasmuch as the amplification factor of the screen grids is substantially unity, in each electrode unit the control grid to screen grid capacitance will be substantially equal to the control grid to anode capacitance. Hence, inasmuch as the alternating current potentials of the anode and screen grid are equal and opposite in phase, the electrostatic effects of these electrodes upon the input circuit will neutralize each other and feedback is substantially prevented.

It will be noted that the conductors 22 may be of very short length so that the inductance thereof is substantially negligible. These conductors constitute the sole electrical connection to the screen grids so that the usual screen grid leading-in conductor, and its inductance, are eliminated. Elimination of this inductance facilitates attainment of stable operation and, as will be apparent, greatly simplifies the circuit design.

It will be appreciated that, inasmuch as only a few turns of relatively small wire will be necessary for the grids 14 because of the low effective amplification factor, the total values of capacitances involving the screen grids will be very small, which, of course, is an important advantage both at ultra high frequencies and in wide band applications.

Two illustrative forms of electron discharge devices constructed in accordance with this invention are shown in Figs. 2 and 3. In the construction illustrated in Fig. 2, the cathodes 11 may be parallel ribbon filaments, and the grids 13 and 14 may be oval helices concentric with the corresponding cathode and carried by uprights or supports 23. As noted, heretofore, the turns of each screen grid preferably are aligned with the turns of the corresponding control grid. The anodes 12 may be U-shaped as shown, each being concentric with the grids corresponding thereto. Beam focussing or space charge suppressor plates 24 may be provided as shown. Alternatively, suppressor grids of the same form as the screen and control grids and coaxial therewith may be employed.

In the construction illustrated in Fig. 3, the cathodes 11 may be parallel linear filaments each encompassed by a cylindrical control grid 13 and a U-shaped screen grid 14. The control and screen grids may be, for example, of the construction disclosed in my Patent 2,062,334, granted December 1, 1936, and may be supported coaxially with the corresponding cathode by supports 27 sealed in the vessel 10. The screen grid wires may be aligned with those of the corresponding control grid. The anodes 12 may be elongated blocks of graphite, supported by leading-in conductors 25 sealed in the vessel 10, each anode having a U-shaped or semicylindrical recess coaxial with the corresponding cathode. Although not shown in Fig. 3 in order to simplify the drawing, suppressor grids, similar in form and construction to the screen grids may be employed.

Fig. 4 illustrates an embodiment of this invention in an electron discharge device comprising a single set of electrodes in an enclosing vessel 10. The electrodes may be planar and parallel to one another or may be coaxially arranged. The screen grid 14 is constructed to have an amplification factor of substantially unity and may have its wires aligned with those of the control grid 13 to minimize the electron current to the screen grid. A suppressor grid may be employed if desired.

The screen grid 14 is connected directly to the anode 12, as by a Lecher loop 26 each side of which has a length equal to one-quarter wavelength for the frequency at which the device is to be operated. Thus, the screen grid 14 is maintained at substantially the same direct current potential as the anode 12 and the alternating potential appearing thereon is of the same magnitude and 180 degrees out of phase with the alternating potential appearing upon the anode. If desired, the screen grid and anode may be connected by a variable Lecher system, external to the vessel 10 and including the leading-in conductors to the screen grid and anode.

The operation of the circuit shown in Fig. 4 will be apparent from the description hereinabove of Fig. 1.

Although specific embodiments of the invention have been shown and described, it will be understood, of course, that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a cathode, a control electrode, an anode, an auxiliary electrode between said control electrode and said anode having an amplification factor of substantially unity, an input circuit connected to said cathode and said control electrode, an output circuit connected to said cathode and said anode, and means for impressing upon said auxiliary electrode a direct current potential substantially equal to the direct current potential of said anode and also a variable potential substantially equal in magnitude and opposite in phase to the variable potential appearing upon said anode by virtue of potential variations in said input circuit.

2. Electron discharge apparatus comprising a plurality of electrodes including a cathode, a control grid encompassing said cathode, an anode coaxial with said grid and a screen grid between said control grid and anode and coaxial therewith, said screen grid having an amplification

factor of substantially unity and the wires thereof being aligned with the wires of said control grid, an input circuit connected to said control grid, an output circuit connected to said anode, and means including a conductor having one end connected to said screen grid and the other end connected to one of said electrodes for impressing upon said screen grid an alternating potential substantially equal in magnitude and opposite in phase to the alternating potential appearing upon said anode by virtue of the alternating potential of said control grid.

3. Electron discharge apparatus comprising a pair of electrode units connected in push-pull relation, each of said units including a cathode, a control electrode, an anode and an auxiliary electrode between the cathode and the anode, and means directly connecting the auxiliary electrode of each of said units to the anode of the other of said units.

4. Electron discharge apparatus comprising a pair of similar electrode units connected in push-pull relation, each of said units including a cathode, a control grid, an anode, and a screen grid having an amplification factor of substantially unity, and a direct connection of substantially negligible inductance between the screen grid of each unit and the anode of the other unit.

5. Electron discharge apparatus comprising an enclosing vessel housing a cathode, an anode, a control grid and a screen grid having an amplification factor of substantially unity, and a phase shifting connection within said vessel between said screen grid and said anode of such impedance that the alternating potentials appearing upon said screen grid and anode by virtue of potentials impressed upon said control grid are substantially equal in magnitude and opposite in phase.

6. Electron discharge apparatus comprising an enclosing vessel housing a pair of similar electrode units, each of said units including a cathode, a control grid encompassing the cathode and coaxial therewith, an anode coaxial with the cathode, and a screen grid between the control grid and anode and coaxial therewith, the screen grid having an amplification factor of substantially unity and having its wires in alignment with the wires of the control grid, and direct connections of substantially negligible inductance between the screen grid of each unit and the anode of the other unit.

ARTHUR L. SAMUEL.