March 8, 1932. J. O. McNALLY 1,848,187

VACUUM TUBE AMPLIFIER

Filed July 9, 1930

FIG. 1.

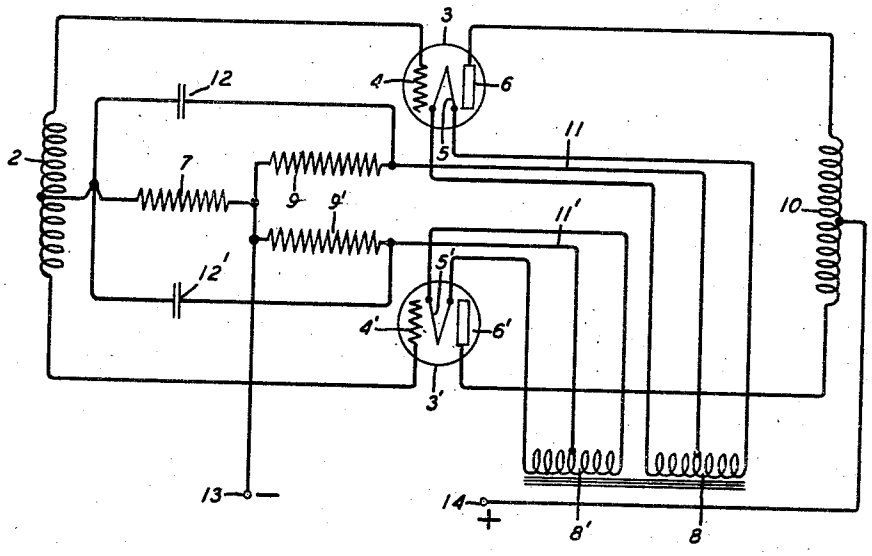
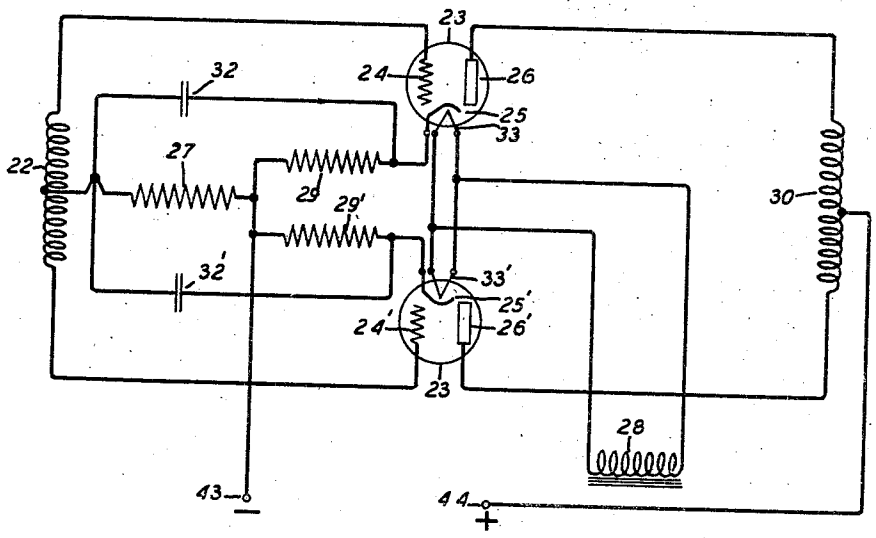


FIG. 2.



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VACUUM TUBE AMPLIFIER

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This invention relates to vacuum tube amplifiers, and more especially to amplifiers in which the vacuum tubes are arranged in push-pull relation.

It is well known that in push-pull amplifiers where either high power or high quality or both are involved the two tubes should be as nearly alike in their characteristics as possible and that if they are not practically identical much trouble is experienced due to undesirable oscillations which may be set up, or to a considerable lowering of the quality of the output of the amplifier. It is also well known especially in high power or comparatively high plate current installations that if for any reason one of the tubes becomes inactive the second tube has impressed upon it such a large increase of plate current that the second tube may be damaged.

An object of this invention is to improve the operation of push-pull vacuum tube amplifiers.

Another object of the invention is to have a high degree of balance between the two sides of a push-pull amplifier without exercising extreme care in choosing the tubes.

A further object is to afford protection to one of the tubes in a push-pull arrangement if the second tube should be accidentally or intentionally cut out of the circuit.

In one embodiment of the invention a grid bias resistance unit is inserted in the plate circuit of each tube between the cathode and the negative side of the plate source. With such an arrangement a slow increase of plate current through one of the tubes above its normal value will change the potential relations between the grid, cathode and anode of the tube in a manner to oppose the increase in the plate current.

With the plate currents held approximately equal, less expensive output transformers may be used since the condition of direct current saturation of the core by excess of current in one winding may be disregarded. A further improvement is noted due to the inherent further elimination of second harmonics.

The invention will be better understood from the following description in connection with the attached drawings, Fig. 1 of which illustrates the invention when applied to the ordinary three-element tube, while Fig. 2 illustrates its use when the equi-potential cathode type of tube is employed.

Referring now to Fig. 1, which is a schematic of an amplifier using space discharge devices arranged in push-pull relation, the secondary winding 2 of an input transformer is shown with its outside terminals connected to the grids 4, 4′ of space discharge devices 3 and 3′, which devices also include filaments or cathodes 5, 5′ and anodes 6, 6′. The mid-point of winding 2 is connected through resistance 7 to the negative terminal 13 of the anode current supply, which is usually made the ground of the amplifier.

The filaments 5, 5′ are heated by alternating current derived from secondary windings 8, 8′ of a power transformer, the primary winding of which may be connected to any convenient source. The source of alternating current and the primary winding have been omitted from the drawings since the arrangement of this apparatus is well known. The mid-point of each winding 8, 8′ is connected through leads 11, 11′ and resistances 9, 9′ to the negative terminal 13 of the anode current source.

The anodes 6, 6′ are connected to the outside terminals of the primary winding 10 of an output transformer. The mid-point of winding 10 is connected to the positive terminal 14 of anode current source in the usual manner.

In push-pull amplifiers using alternating current for filament heating heretofore used, it has been customary to connect the filaments in parallel to one winding of the power transformer. A connection from the mid-point of the winding containing a resistance shunted by a condenser to the mid-point of the transformer secondary completed the input circuit for both space discharge devices. With such an arrangement the grids of both devices have been maintained at the same potential.

In the present arrangement as pointed out, above, each filament has a separate winding and separate resistances are used in each filament return.

In circuits involving the use of a resistance

in the plate circuit to establish grid bias, resistance capacity filtering is provided in the grid circuits. The filter for grid 4 comprises resistance 7 and condenser 12. That for grid 4′ comprises resistance 7 and capacity 12′. Resistance 7 is large in comparison with 9 or 9′ and is effective together with the condensers in preventing rapid variations in space current due either to the signal or to hum or noise components from reaching the grids. Resistances 9 and 9′ although forming part of the resistance path in parallel to the condensers do not really form a part of the filter. It is because of the ripple likely to occur in resistances 9 and 9′ that the filters are necessary.

The operation of push-pull amplifiers is well understood and hence will not be repeated here except as to the direct current anode circuit. The anode direct current path for device 3 may be traced from the positive terminal 14 of the anode current source through the upper part of winding 10 to anode 6, and from filament or cathode 5, winding 8 of power transformer, lead 11, resistance 9 to the negative terminal 13 of the source. A similar path including the lower half of winding 10 and resistance 9′ may be traced for device 3′.

An IR drop occurs in resistance 9 (or 9′) by the passage of anode current therethrough and this drop determines the potential of the filament above that of the negative terminal of the anode current source or ground. Since practically no direct current flows through the grid circuit, the IR drop through resistance 7 may be disregarded and the grids considered to be at the potential of the negative terminal of the anode current source or ground.

However, if the anode current varies, the IR drop through resistance 9 (or 9′) will vary and the potential of the filament will also vary. If the anode current should increase, the IR drop through the resistance will increase and the potential of the filament becomes more positive. The effect is the same as if the grid became more negative and the anode less positive. That is, there would be a reduction in anode current flow. The opposite action occurs if the anode current should fall below its normal value. In such case the filament becomes less positive or, putting it the other way, the grid becomes less negative and the anode more positive.

This control action occurs no matter what the cause of the change may be. In the case of a single resistance to control the bias of both tubes, if one tube should be removed from the circuit there is a tendency for the current through the other tube to greatly increase, which increase if maintained would probably damage the tube. The same is true if by accident the anode current through one tube is cut off. In any case, the arrangement functions to bring the anode current in each tube back to its normal value.

The most important function, however, of this arrangement is to maintain balance between two tubes which do not have identical characteristics. In such a case, the resistances 9 and 9′ may be given such values as to provide a normal grid bias for each tube, in which case the current through both tubes are approximately equal and hence there is practically no unbalance.

In Fig. 2 equi-potential cathode or heater type tubes are used. In this case the heating elements 33 and 33′ are connected in parallel to a single winding 28 of the power transformer. Whereas the heating elements are shown connected in parallel the invention should not be so limited as a series connection will function as well and in some cases is preferred. The cathodes 25 and 25′ are directly connected to resistances 29 and 29′, respectively. The anode direct current path for tube 23 may be traced from the positive terminal 44 of the anode current source through the upper half of winding 30, anode 26, cathode 25, resistance 29 to the negative terminal 43 of the source. Variations in anode current flow vary the potential of the cathode with the same result as described in detail in connection with the circuit of Fig. 1.

It is to be understood that whereas but two embodiments of the invention relating to amplifiers have been described, the invention is also applicable to oscillators and therefore is to be limited only by the scope of the appended claims.

What is claimed is:

1. A vacuum tube amplifier comprising vacuum tubes arranged in push-pull relation, each tube containing a control grid, a cathode and an anode, an anode circuit for each tube and means comprising an individual impedance in each anode circuit to control the potential difference between each grid and its associated cathode.

2. A vacuum tube amplifier comprising vacuum tubes arranged in push-pull relation, each tube containing a control grid, a cathode and an anode, an anode circuit for each tube and an individual resistance in each anode circuit by means of which the potential of the grid is controlled relative to the potential of the cathode.

3. In an electric circuit, vacuum tubes arranged in push-pull relation, each tube including a control electrode, a cathode and an anode, means to insure equal anode direct current flow in each tube comprising a separate resistance element in each anode circuit, the IR drop through which, due to the anode current, controls the potential differences between the electrodes of the corresponding vacuum tube.

4. In an electric circuit, vacuum tubes arranged in push-pull relation, each tube in-

cluding a control electrode, a cathode and an anode, means to insure equal anode direct current flow in each tube comprising a separate resistance element in each anode circuit connected between the corresponding cathode of each tube and the negative terminal of the anode current source, the IR drop through which, due to the anode current, controls potential differences between the electrodes of the corresponding vacuum tube.

5. In an electric circuit, vacuum tubes arranged in push-pull relation, each tube including a control electrode, a cathode and an anode, a common source of anode current, independent cathode energizing sources, a connection including a resistance from each of said cathodes to the negative terminal of said source of current, and connections from the grids to said terminal.

6. In an electric circuit, vacuum tubes arranged in push-pull relation, each tube including a control electrode, a cathode and an anode, a connection between each cathode and its associated control electrode, a separate resistance included in each said connection, a resistance common to both said connections and a separate condenser in shunt to that portion of each connection containing said resistances.

In witness whereof, I hereunto subscribe my name this 7th day of July, 1930.

JAMES O. McNALLY.