April 30, 1935. W. H. T. HOLDEN 1,999,327

AMPLIFYING SYSTEM

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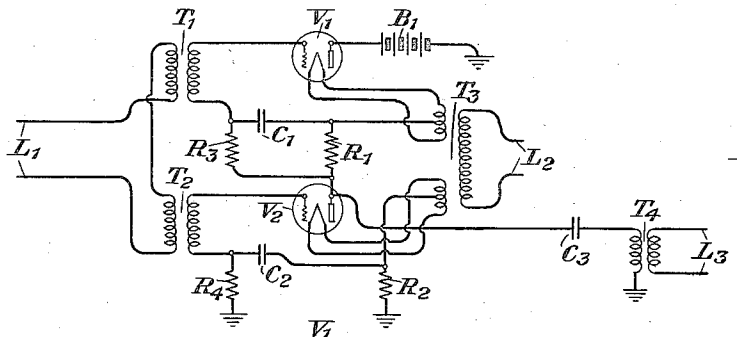

Fig. 1

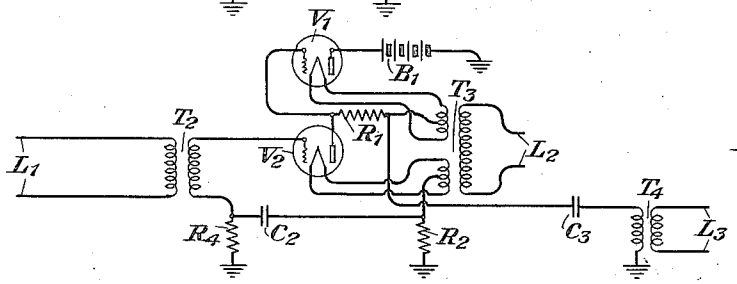

Fig. 2

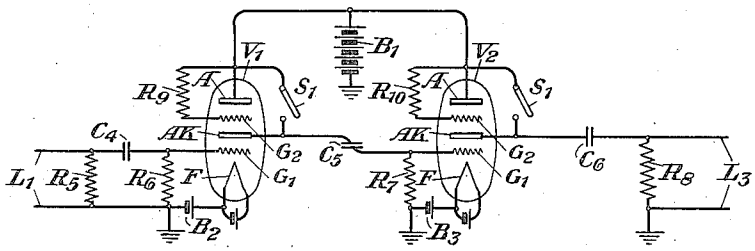

Fig. 3

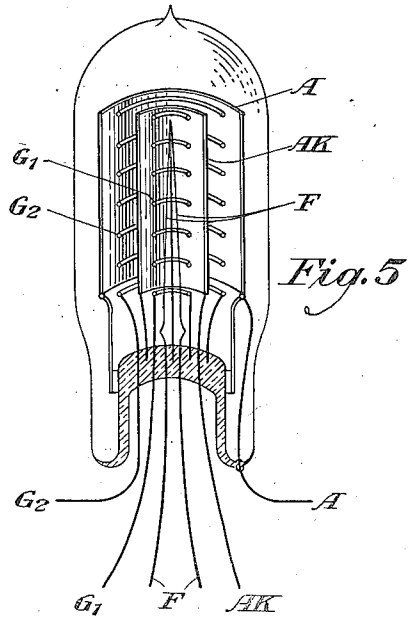

Fig. 5

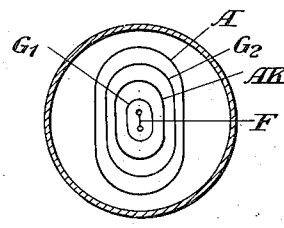

Fig. 4

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AMPLIFYING SYSTEM

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3 Claims. (Cl. 179—171)

This invention relates to vacuum tubes and circuits for vacuum tubes employed to transmit and amplify electrical energy which may be in the form of signals or other currents.

This invention may find special application in amplifying circuits. When reduced to its fundamental elements the invention may be considered to comprise two vacuum tubes which have their space current paths connected in series relationship. One of the tubes is employed as a coupling impedance for the other tube.

This invention will be better understood from the detailed description hereinafter following, when read in connection with the accompanying drawing, in which Figures 1, 2 and 3 represent different forms of series connected vacuum tube amplifying circuits and Figs. 4 and 5 show different views of the type of vacuum tube employed in the arrangement disclosed in Fig. 3.

Referring to Fig. 1 of the drawing, there is shown two similar vacuum tubes designated V_1 and V_2, the grid circuits of which are coupled to an incoming line L_1 through transformers T_1 and T_2, respectively. The primary windings of the transformers T_1 and T_2 are oppositely poled so that the grid circuits of the tubes V_1 and V_2 will be supplied with the incoming signaling energy in two different phases which are 180 degrees apart.

A source of alternating current is connected by means of the circuit L_2 to the primary winding of transformer T_3, which has two secondary windings. One of these secondary windings, i. e. the lower winding, is connected to the filament of the tube V_2 and the other, i. e. the upper secondary winding, is connected to the filament of the tube V_1 and the current supplied by these secondary windings is employed to heat these filaments to electron-emitting temperatures.

The plate circuits of the tubes V_1 and V_2 are connected in series relationship in a circuit which includes a battery B_1, plate and filament electrodes of the tube V_1, the upper secondary winding of the transformer T_3, a resistance R_1, the plate and filament electrodes of the tube V_2, the lower secondary winding of the transformer T_3, resistance R_2 and ground. The battery B_1 is one of high potential and it is used to bring the plates of the tubes V_1 and V_2 at proper positive potentials with respect to corresponding filaments of these tubes. The grid circuit of the tube V_1 includes the secondary winding of the transformer T_1 and a condenser C_1 and it extends to the midpoint of the upper secondary winding of the transformer T_3. Similarly, the grid circuit of the tube V_2 includes the secondary winding of the transformer T_2, the condenser C_2, and extends to the midpoint of the lower secondary winding of the transformer T_3. By virtue of the connection of the resistances R_1 and R_2 in series with the space discharge paths of the tubes V_1 and V_2 which are supplied with direct current potential by battery B_1, direct current voltages are generated across the terminals of resistances R_1 and R_2 and these voltages are employed to normally bias the grid electrodes of the tubes V_1 and V_2, respectively, at suitable negative potentials. The alternating current energy that flows between the plate and filament electrodes of the tube V_2 becomes transmitted through a condenser C_3 and through the primary winding of the transformer T_4. This energy is then delivered to an outgoing line designated L_3.

There is a tendency for alternating voltages to become generated by the resistances R_1 and R_2 due to the presence of signaling energy in the plate circuits of the tubes V_1 and V_2. These alternating voltages would become impressed upon the grid electrodes of the tubes V_1 and V_2 and interfere with the maintenance of proper biasing potentials for these electrodes. In order to suppress the effect of these alternating potentials upon the grid electrodes of the tubes V_1 and V_2, a form of filtering circuit is connected to these resistances. One of these filtering circuits includes the condenser C_1 and the resistance R_3 which are connected in series relationship across the terminals of resistance R_1 and the other of these filtering circuits includes the condenser C_2 and the resistance R_4 which are connected in series relationship across the terminals of the resistance R_2.

Inasmuch as the primary windings of the transformers T_1 and T_2 are oppositely poled, energy coming in over line L_1 will reach the grids of the tubes V_1 and V_2 in such a way that when one of these grids is at a high negative potential, the potential on the other will be practically negligible. This will cause the voltage to ground at some point in the circuit between the filament of the tube V_1 and the plate of the tube V_2 to fluctuate with respect to ground. The circuit of the primary winding of the transformer T_4 is connected to ground from the plate of the tube V_2 and this circuit transmits the signaling energy in amplified form to the outgoing circuit L_3.

The condenser C_3 is employed to separate the alternating current path of the signaling energy from the direct current path for the current supplied by the battery B_1. It will be noted that the

lower terminal of the resistance R_1 is connected to ground through two similar paths which respectively include the plate and filament electrodes of the tubes V_1 and V_2. Consequently, the impedance of these two parallel paths is one-half that of the plate filament impedance of either tube. Inasmuch as the energy supplied to the grid circuits of the tubes V_1 and V_2 is separated into two portions which are displaced in phase by 180 degrees, only currents having this phase displacement will appear in the circuit including the condenser C_3 and the primary winding of the transformer T_4. Therefore, the even harmonic frequencies will flow in the series circuit which includes the battery B_1 and the plate and filament electrodes of the tubes V_1 and V_2, described hereinabove. The characteristics of the arrangement shown in Fig. 1 are the same as those characteristic of any form of push-pull amplifier well known in the art.

The arrangement shown by Fig. 2 of the drawing is similar in many respects to that of Fig. 1, yet it eliminates the input transformer T_1 of Fig. 1 which is employed to supply signaling energy to the grid circuit of the tube V_1. In the arrangement of Fig. 2, the incoming signaling energy directly reaches only the vacuum tube V_2 through the transformer T_2. The space current path of the arrangement of Fig. 2, as in Fig. 1, includes the battery B_1 and the plate and filament electrodes of the tube V_1, the upper secondary winding of transformer T_3, the resistance R_1, the plate and filament electrodes of the tube V_2, the lower secondary winding of the transformer T_3, the resistance R_2 and ground. It is to be noted that the resistance R_1 is not by-passed by any form of filter as in Fig. 1. Moreover, the resistance R_1 is in series with the primary winding of the transformer T_4 which supplies the signaling energy in amplified condition to the outgoing circuit L_3. The interconnected circuit for the primary winding of the transformer T_4 includes the resistance R_2, the lower secondary winding of the transformer T_3, the filament and plate electrodes of the tube V_2, the resistance R_1, the condenser C_3, the primary winding of the transformer T_4 and ground. The latter circuit causes alternating potentials to be generated by the resistance R_1 by virtue of the flow of signaling energy therethrough, and these potentials are generated in addition to the direct current potentials caused by the flow of ordinary space current from the battery B_1. These alternating potentials will be repeated through the grid circuit of the tube V_1 and will, of course, be amplified by that tube.

Fig. 3 shows an amplifying system interconnecting the incoming circuit L_1 with the outgoing circuit L_3 which includes two similar tubes V_1 and V_2 of special construction and which will be more completely described with reference to Figs. 4 and 5. The incoming circuit L_1 terminates in a resistance R_5. The signaling voltages impressed across the resistance R_5 are transmitted through a condenser C_4 to a resistance R_6 and these voltages reach resistance R_6 and fluctuate the voltage applied to the grid G_1 of the tube V_1 with respect to its filament F. A battery B_2 is employed to provide the initial bias for the grid G_1 about which the signaling voltages normally fluctuate.

After the amplification of the signal currents by the tube V_1, the operation of which will be subsequently described, the amplified currents traverse a condenser C_5 and similarly produce corresponding voltages across a resistance R_7. The fluctuating potential impressed upon the grid G_1 of the tube V_2 is also changed in accordance with the amplified currents and this change occurs about a normal biasing potential produced by a battery B_3. The energy amplified by the tube becomes transmitted through a condenser C_6 and then through a resistance R_8 which bridges the outgoing circuit L_3. This resistance supplies the outgoing circuit with the amplified energy.

The tubes V_1 and V_2 are of special construction. Their component elements are shown in Figs. 4 and 5, which represent horizontal and vertical sections of each tube. Each tube includes, in addition to a filament F and a grid G_1, a combination anode and cathode designated AK, another grid designated G_2, and an anode designated A. All of these elements are enclosed within a bulb which is preferably evacuated or reduced to a pressure so low that any effects which may be due to gaseous ionization are substantially eliminated.

The element AK may be arranged to surround the filament F and the grid G_1. It is coated externally with a thermionically active material, preferably an oxide well known in the vacuum tube art which is employed for coating filaments or cathodes, and this external material, when brought to an almost red heat, will emit electrons freely. The element AK may be maintained at an electron-emitting temperature by the bombardment of electrons flowing to it from the filament F.

The electrons emitted from the outer surface of the element AK flow toward the grid G_2 and then to the anode A. The grid G_2 may be biased either positively or negatively with respect to the element AK, as desired. However, in accordance with this invention, the grid G_2 is preferably biased positively so as to assist in maintaining a large electronic emission from the element AK to the anode A.

The inner surface of the element AK is preferably coated with a pure metallic substance. This inner surface acts as an anode and receives electronic emission from the filament F under the control of the grid G_1.

As shown in Figs. 4 and 5, the various elements of the tube are arranged concentrically about the filament F. The filament F is surrounded by the grid G_1, and the grid G_1 is surrounded by the element AK. The grid G_2 surrounds the element AK and the anode A is the outermost element. All of these elements are, of course, suitably spaced from each other and are enclosed in a glass bulb which, as stated hereinabove, is practically exhausted to a negligible pressure or vacuum.

To start both of the tubes V_1 and V_2 in proper operation, the switches S_1 and S_2 are closed. These switches connect the positive terminal of the battery B_1 to the elements designated AK in the tubes V_1 and V_2 and, therefore, electronic emission may take place between the filament F and the element AK. After this electronic emission has been maintained for a brief interval of time, the element AK itself becomes very hot and it also emits electrons which flow to the anode A under the control of the grid G_2. Both switches S_1 and S_2 may then be opened and the tubes V_1 and V_2 will continue to operate, each with two continuous electronic emissions which occur simultaneously, one from the filament F to the element AK, and the other from the element AK to the anode A. It is to be noted that the resistances R_9 and R_{10} connect the grids G_2 of the tubes V_1 and V_2, respectively, to the anodes designated A of these tubes, and it will be apparent that

these resistances are employed to maintain the grids G_2 at a lower positive potential than the anode A with respect to the corresponding element AK.

The arrangement shown in Fig. 3 has certain decided advantages over other arrangements because of its employment of the special form of vacuum tube. The arrangement of Fig. 3 eliminates as much as possible the size of the external leads which extend to the coupling impedances of the tubes V_1 and V_2, these coupling impedances being provided by the elements AK and A, which are located within the envelopes of these tubes. As compared with ordinary push-pull vacuum tube amplifying circuits, the coupling impedances of the tubes V_1 and V_2 of Fig. 3 are comparatively smaller and at least as good results are obtained. Moreover, the arrangement is practically distortionless and aperiodic for all frequencies below about 10,000 kilocycles, and the transmission characteristic of the arrangement is very flat. Furthermore, the prevention of the flow of direct current through the alternating current output circuits is easily obtained.

While this invention has been shown and described in certain particular arrangements merely for the purpose of illustration, it will be understood that this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The combination of an input circuit, an output circuit, an amplifier interconnecting said input circuit and said output circuit, said amplifier including two vacuum tubes each of which embodies plate, filament and grid electrodes and two additional electrodes, said plate electrode being externally coated so as to be thermionically active, and means including said two additional electrodes to produce a space discharge path between said plate electrode and said two additional electrodes so as to act as the coupling impedance for the tube.

2. An amplifying system comprising first and second vacuum tubes each having a filament, first and second grid electrodes and first and second plate electrodes, an input circuit connected to the first grid electrode and filament of the first vacuum tube, an output circuit connected to the first plate electrode and filament of the second vacuum tube, two resistances each connected between the second grid electrode and the second plate electrode of each tube, a condenser connected between the first plate electrode of the first tube and the first grid electrode of the second tube, a resistance connected between the first grid electrode and the filament of the second vacuum tube, and a source of direct potential connected in parallel between the second plate electrodes of both tubes and the filaments of these tubes.

3. An amplifying system comprising first and second vacuum tubes each having a filament, a first grid electrode, an anode-cathode, a second grid electrode and an anode, the anode-cathode of each tube receiving electrons from the filament and emitting electrons to the anode, an input circuit connected between the first grid electrode and the filament of the first vacuum tube, an output circuit connected between the filament and the anode-cathode of the second vacuum tube, two resistances each connected between the second gird electrode and the anode of each vacuum tube, a condenser connected between the anode-cathode of the first vacuum tube and the first grid electrode of the second vacuum tube, a resistance connected between the first grid electrode of the second tube and its filament, and a source of direct potential connected in parallel between the anodes of both tubes and their filaments.

WILLIAM H. T. HOLDEN.