

Feb. 12, 1935.

R. S. GLASGOW
VOLUME CONTROL SYSTEM

1,991,277

Filed May 1, 1929

2 Sheets-Sheet 1

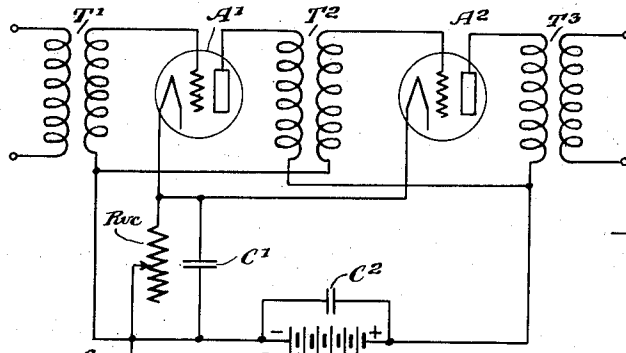


Fig. 1.

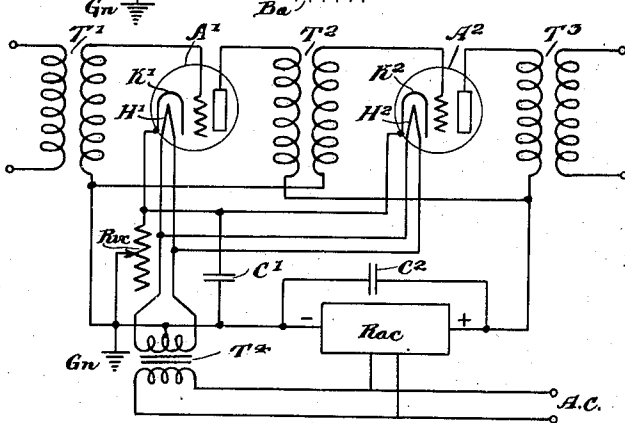


Fig. 2.

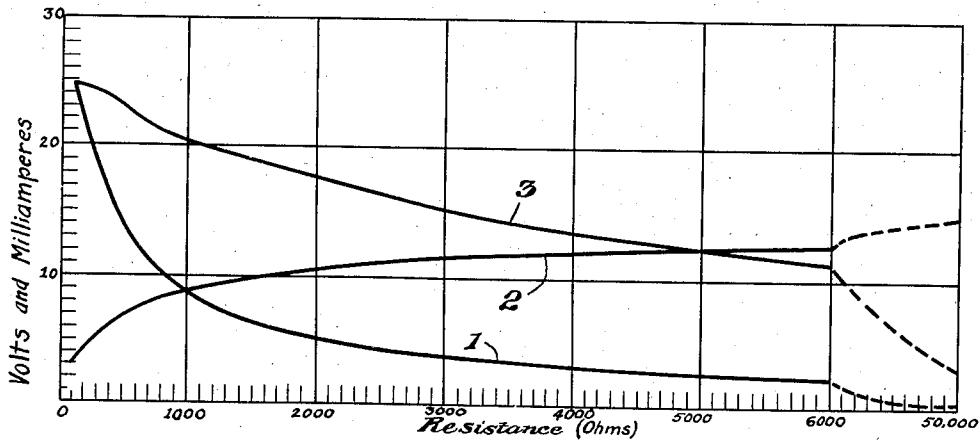


Fig. 4.

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2 Sheets-Sheet 2

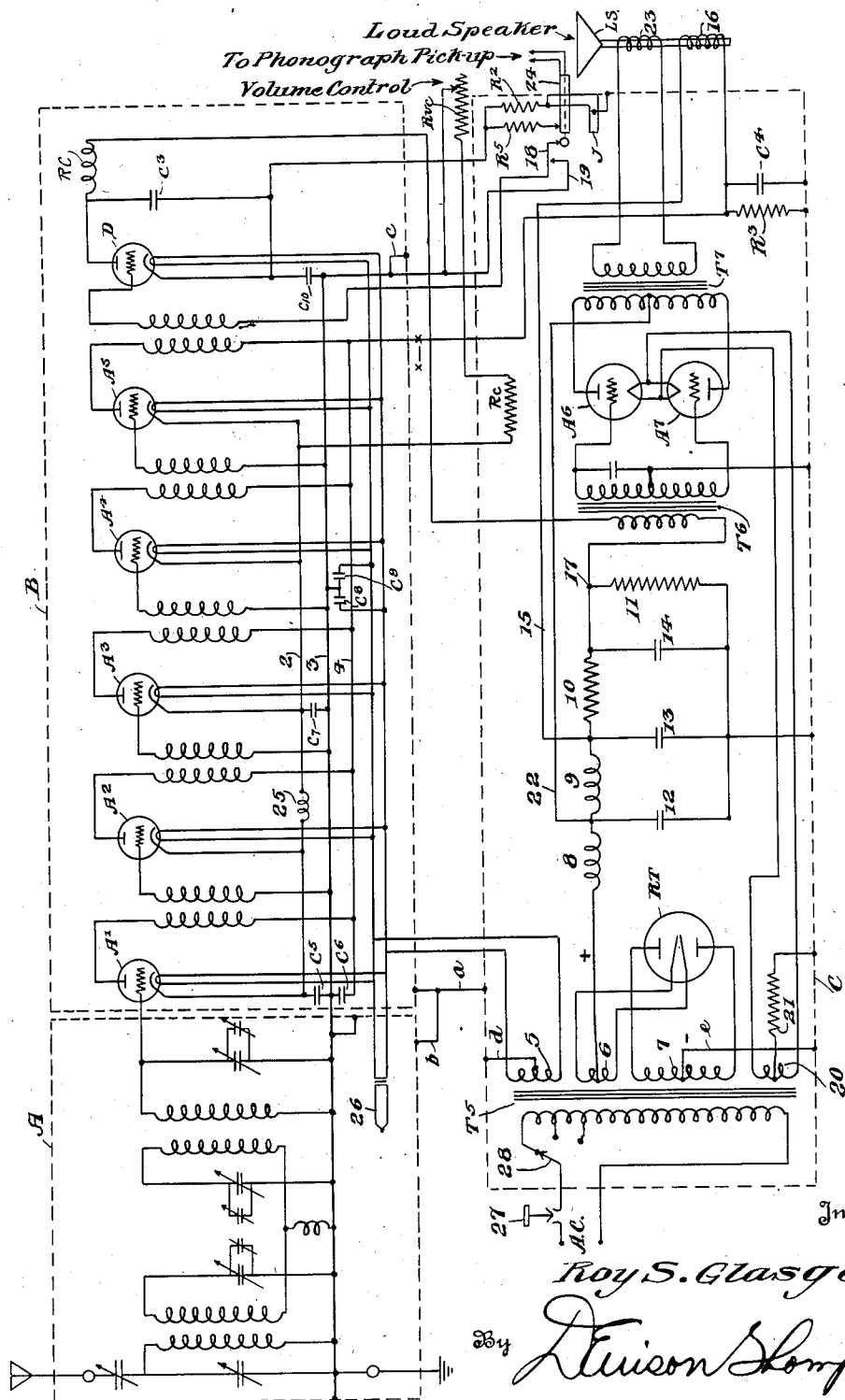


Fig. 3.

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UNITED STATES PATENT OFFICE

1,991,277

VOLUME CONTROL SYSTEM

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Application May 1, 1929, Serial No. 359,536

4 Claims. (Cl. 179—171)

This invention relates to a volume control system for vacuum tube amplifiers. My invention also involves a novel method of volume control for vacuum tube amplifiers.

5 An object of the invention is to devise a system for controlling the amplification or gain of a vacuum tube amplifier with a minimum distortion of the amplified current.

10 It has heretofore been proposed to vary the amplification or gain of vacuum tube amplifiers by means of a variable resistance inserted in the plate circuit. The principal objection to this system of volume control is that a very large resistance is required to reduce the volume to substantially zero. For example, when this system is applied to ordinary broadcast receivers the maximum value of the resistance required to reduce the signal from a strong local station to substantially zero volume may be in excess of 10,000,000 ohms.

15 An object of my invention is to devise a volume control system in which a variable resistance inserted in the plate circuit simultaneously serves to control the plate current and to vary the biasing potential applied to the grid element of the amplifier. The resistance is inserted in a common path of the grid and plate circuits, whereby as the resistance increases to decrease the plate current, the grid biasing potential is rendered more negative, which also tends to reduce the plate current. Thus, the resistance is doubly effective in controlling the plate current. By such an arrangement I am enabled to obtain full range of volume variation from zero to a maximum with a resistance having a value of only a fraction of that required when the resistance serves to control the plate current only.

20 My invention is illustrated in the accompanying drawings in which;

25 Figure 1 illustrates my invention as applied to a two-stage amplifier;

30 Figure 2 shows the volume control system applied to a two-stage amplifier employing vacuum tubes having uni-potential cathodes;

35 Figure 3 shows the volume control system applied to a radio receiver; and

40 Figure 4 is a graph with curves showing the variation in plate current and grid biasing potential with changes in the volume control resistance.

45 Referring to Figure 1, I have shown two transformer-coupled amplifiers A1 and A2. T1, T2 and T3 indicate, respectively, the input transformer, the coupling transformer, and the output transformer. Amplifier tubes A1 and A2 may be either of the filamentary cathode type or of the

uni-potential cathode type. The cathodes of amplifiers A1 and A2 are connected in parallel and to one terminal of a volume control resistance Rvc. The other terminal of the volume control resistance is connected to the negative terminal of a suitable source of plate current Ba. The positive terminal of the source of plate current is connected to the primary windings of transformers T2 and T3 to complete the plate circuits of tubes A1 and A2. The secondary windings of transformers T1 and T2 are included in the input circuits of amplifiers of A1 and A2, respectively, but instead of being connected directly to the cathode in the usual manner, the common cathode return terminal of the input circuits is connected around the volume control resistance Rvc so as to include this resistance in each input circuit. The variable contact of the volume control resistance is preferably connected to the point to which the input circuits are connected to the plate circuit, and this point is preferably grounded as shown at Gn. The volume control resistance Rvc is preferably shunted by a condenser C1 of substantial capacity, and the plate supply source Ba is also preferably shunted by a condenser C2.

Operation of Figure 1 is as follows: From an inspection of the diagram, it will be seen that the volume control resistance Rvc is included in the plate circuit of each amplifier, and is also included in each input circuit. The drop in potential produced by the plate current flowing through the volume control resistance is of such polarity that the grids of the amplifiers are maintained negative with respect to the cathodes, the value of the biasing potential depending upon the value of the total plate current and the value of the volume control resistance. Increasing the volume control resistance increases the external resistance of the plate circuits, and, therefore, flattens out the plate current characteristic and reduces the amplification or gain of the amplifier. The plate current is not only reduced by the direct action of the increased volume control resistance, but is also further reduced by the increased negative biasing potential applied to the grids of the amplifiers. The circuit constants are such that with increase in volume control resistance Rvc, the negative biasing potential due to the drop across the volume control resistance increases continuously over the working range of the volume control resistance. It will thus be seen that the volume control resistance, when placed in the position shown, is doubly effective in reducing the plate current, and for this reason a rela-

tively small resistance may be employed as compared with the resistance which would be required to reduce the plate current to the same extent when such resistance is not included in the grid circuits of the amplifier. This feature will be explained in more detail hereinafter in connection with Figures 3 and 4.

In Figure 2 the invention is illustrated in connection with a two-stage amplifier employing vacuum tubes of the uni-potential cathode type in which the heater elements of the tubes are heated from an alternating source of current, and in which the plate circuits are supplied with rectified alternating current. In this figure, elements corresponding to similar elements in Figure 1 are indicated by the same reference characters. The circuit diagram is very much like that shown in Figure 1. The uni-potential cathodes K1 and K2 are connected together and to one terminal of the volume control resistance R_{vc} . The heater elements H1 and H2 are connected in parallel, and are supplied with heating current from the secondary of transformer T4 connected to an alternating current supply line AC. The midpoint of the secondary winding of transformer T4 is connected to ground. The plate current for the amplifier tubes is supplied from a rectifier Rac connected to the alternating current line AC, and the circuit is otherwise the same as illustrated in Figure 1.

The operation of Figure 2 will be apparent from the description of the operation of Figure 1.

Figure 3 illustrates my invention as applied to a commercial radio receiver. The radio receiver comprises a tuner compartment A, an amplifying and detecting compartment B, and a compartment C containing the audio frequency amplifiers and the power supply units. Compartments A, B and C comprise metallic casings which are connected together by suitable bonding connections indicated at (a) and (b).

The tuning compartment A contains suitable tuning apparatus for selecting the desired wave, which apparatus forms no part of the present invention, and is not described in this application.

Compartment B contains a radio frequency amplifier comprising five transformer-coupled vacuum tube amplifiers A1, A2, A3, A4 and A5, and a vacuum tube detector D. The vacuum tubes employed are of the uni-potential cathode type with heater. The uni-potential cathodes of the amplifiers are connected to a common connection 2 which is grounded to the metallic casing of compartment B as at (c) through a connection including a fixed resistance R_c in compartment C and the volume control resistance R_{vc} . The cathode-return terminals of the input circuits of the amplifiers are connected to a common connection 3 which is connected to the metallic casing of compartment B as indicated at (c). The heaters of the amplifier and detector tubes are supplied with heating current from secondary winding 5 of transformer T5. The midpoint of secondary winding 5 is grounded to the metallic casing C as indicated at (d). The plate current supply source for the amplifier and detector tubes includes a full wave rectifier tube RT, the filament of which is heated from winding 6, and the plate elements of which are connected to opposite terminals of winding 7. The midpoint of winding 7, which constitutes the negative terminal of the plate current supply, is grounded to the metallic casing C as indicated at (e). The midpoint of winding 6, which constitutes the positive terminal of the

rectifier, is connected to a filter unit including choke coils 8 and 9, resistance 10 and 11, and condensers 12, 13 and 14. Choke coils 8 and 9 and resistance 10 are included in series in the positive side of the plate supply circuit, while resistance 11 and condensers 12, 13 and 14 are connected in shunt to the plate supply circuit as shown. The plate circuit for the radio frequency amplifiers A1 to A5 is completed from the positive side of the rectifier filter through wire 15 to winding 16 of the loud speaker LS, and through winding 16 to a common wire 4, to which the plate circuits of the radio frequency amplifiers are connected. The plate circuit of the detector D is completed from positive terminals 17 of the rectifier filter through primary winding of transformer T6, through radio frequency choke coil RC, to the plate element of the detector. The cathode of detector D is grounded to the metallic casing C by a connection including biasing resistance R2 which is connected to the frame of a jack J mounted on metallic compartment C. A by-pass condenser C3 is connected between the plate and cathode elements of detector D to by-pass the radio frequency current, and a by-pass condenser C10 is connected from the detector cathode to the conductor 3 and to the casing B by connection C. The cathode-return terminal of the input circuit of detector D is grounded to metallic compartment B and to wire 3 through normally closed jack contacts 18 and 19. The midpoint of the secondary winding of transformer T6 is grounded to metallic casing C, and the end terminals of the winding are connected, respectively, to the grids of a push-pull amplifier A6-A7. The cathodes of amplifiers A6 and A7 are heated by current supplied from winding 20 of transformer T5. The midpoint of winding 20 is grounded to casing C through a biasing resistance 21. The plate elements of amplifiers A6 and A7 are connected respectively to opposite terminals of the primary winding of transformer T7, and plate current is supplied to these amplifiers by a connection 22 from between choke coils 8 and 9 on the rectifier filter to the midpoint of the primary winding of transformer T7. The secondary of transformer T7 is connected to the operating winding 23 of loud speaker LS. A resistance R3 shunted by a condenser C4 is connected from one terminal of magnetizing winding 16 of loud speaker LS to metallic casing C for the purpose of supplying additional magnetizing current to winding 16 over that supplied by the plate currents of amplifiers A1 to A5.

24 indicates a plug the leads of which are connected to a phonograph pick-up device whereby the audio frequency part of the radio receiver may be employed for the electric reproduction of phonograph records. The sleeve of plug 24 is adapted to make connection with a jack contact to connect resistance R5 in parallel with resistance R2, to thereby place a proper biasing voltage upon the grid of detector D for operation as an amplifier. The tip of plug 24 makes contact with spring contact 18 of jack J to complete the grid circuit of detector D through the phonograph pick-up device and to open contact between contacts 18 and 19. With this arrangement detector D is in proper condition to function as an amplifier for supplying amplified phonograph reproduction to the input of the push-pull amplifiers A6-A7.

By-pass condensers C5, C6 and C7 are provided to prevent undesirable couplings between conductors 2, 3 and 4. High-frequency choke coil 25 is provided to prevent undesirable coupling be-

tween the amplifiers on opposite sides of the coil. By-pass condensers C8 and C9 are connected in series across the filament heater energizing circuit of the amplifier, and the midpoint of these condensers is connected to conductor 3, which is grounded, for the purpose of preventing undesired coupling of high frequency currents by way of the filament energizing circuit. 26 indicates a lamp energized from the heater circuit for illuminating the tuner dial and for indicating when the heaters are energized. The primary circuit of power transformer T5 is provided with a control switch 27, and a variable tap 28 for adjusting the number of primary turns to suit the voltage of the alternating current supply line AC.

From an inspection of the circuit diagram shown in Figure 3, it will be seen that insofar as the volume control feature is concerned, the diagram is the same as that shown in Figure 2, except that there are five amplifier tubes employed instead of two, and there is a fixed resistance Rc connected in series with volume control resistance Rvc. When the arrangement is operated as a radio receiver, plug 24 is withdrawn from jack J, and a high negative biasing voltage is impressed on the grid of detector D by the drop in potential across resistance R2. With the volume control resistance Rvc adjusted to maximum volume, that is, all the volume control resistance cut out, the drop in potential across resistance Rc impresses a proper negative biasing potential upon the grids of amplifiers A1 to A5. Upon adjusting the volume control resistance to decrease the volume from maximum, the biasing potential impressed upon the grids of the amplifiers is determined by the voltage drop across the combined resistance Rc and Rvc. The effect of increasing the volume control resistance is the same as explained above in connection with Figures 1 and 2, that is, it acts to directly decrease the plate current in the amplifiers, and also indirectly to decrease the plate current by increasing the negative grid bias.

For the purpose of showing the effectiveness of my system of volume control, the curves shown in Figure 4 have been reproduced from actual test of the volume control as applied to the radio receiver shown in Figure 3. Curve 1 indicates the variation in total plate current for the amplifiers with variations in the biasing resistance, that is, in the combined resistance of Rc and Rvc. Curve 2 indicates the change in biasing potential with changes in biasing resistance. Curve 3 is reproduced to show the difference between my system of volume control and the prior system wherein the volume control resistance affects merely the value of the plate current, and the grid bias remains constant. Curve 3 was obtained by removing resistances Rc and Rvc from the position shown in Figure 3 and inserting them in the common plate circuit of the amplifiers at the point indicated at X, and in the place of resistance Rc and Rvc, a biasing battery of a voltage equal to the drop across resistance Rc with all the volume control resistance cut out was inserted to maintain the grids at a constant negative potential with respect to the cathodes. In the particular set tested, the value of Rc was of the order of 120 ohms, and the maximum value of Rvc was substantially 50,000 ohms. At full volume setting the total plate current was of the order of 25 milliamperes and the grid biasing voltage was of the order of 3 volts. The solid portion of the curves indicate the variations up to 6,000 ohms, and the dotted portion of the curves indicates the variation on a reduced scale from 6,000 to 50,000

ohms, or to the minimum volume position. From an inspection of the curves, it will be seen that the grid biasing potential constantly increases with increasing volume control resistance; at full volume the negative bias is of the order of 3 volts, and at minimum volume the negative bias is of the order of 15 volts. The plate current decreases continuously from a maximum of the order of 25 milliamperes at maximum volume to a minimum of the order of 0.3 of a milliampere. As shown by curve 3, with the volume control resistance connected so as to vary the plate current alone, and with the grid biasing potential held constant at substantially 3 volts, the plate current varies from a maximum of substantially 25 milliamperes to a minimum of substantially 3 milliamperes.

In the reception of a strong local station using my system of volume control, comfortable volume obtained with the control set at about 6,000 ohms. The signal completely disappeared at about 13,000 ohms, long before the full value of the volume control resistance had been inserted in the circuit, whereas with the volume control resistance inserted in the position represented by curve 3, when the full value of the volume control resistance had been included in the plate circuit, the signal strength was reduced only slightly below the normal volume reception of the station obtained by my system with only 6,000 ohms inserted.

From this one example, it will be seen that a resistance of 6,000 ohms in my volume control is more effective than 50,000 ohms in the prior system. A distinct advantage is thereby gained since it is very difficult to manufacture variable resistances of high values with any degree of uniformity and constancy.

While I have given above certain numerical values solely for the purpose of illustrating the operation of my invention, it will be understood that the invention is not to be limited in its application to any particular constants. It will also be understood that my system of volume control may be applied to either high or low frequency amplifiers.

What I claim is:

1. In an amplifier, an electron device having a cathode, an anode and a control electrode, a resistance having one end connected to said cathode, an output circuit containing a source of direct current potential connected at one end to said anode and at the other end to the remaining end of said resistance and an input circuit connected at one end to said control electrode and at the other end to said remaining end of the resistance and means to vary said resistance to simultaneously vary in the same sense the internal and external impedances of said electron device to doubly control the volume of the amplifier.

2. The method of controlling the volume of an electron device having a control electrode and an anode-cathode circuit containing a source of current and internal and external impedances which consists in varying the external impedance and simultaneously varying the internal impedance to doubly control the current in said anode-cathode circuit.

3. The method of controlling the volume of an electron device having a control electrode and an anode-cathode circuit containing a source of current and internal and external impedances which consists in varying the said external impedance and simultaneously applying to said control electrode a negative voltage drop across

a portion of said external impedance to doubly control the current in said anode-cathode circuit.

4. In an amplifier, an electron device having a cathode, an anode and a control electrode, a resistance having one end connected to said cathode, a condenser shunting said resistance, an output circuit containing a source of direct current potential connected at one end to said anode

and at the other end to the remaining end of said resistance, and an input circuit connected at one end to said control electrode and at the other end to said remaining end of the resistance, and means to vary said resistance to simultaneously vary in the same sense the internal and external impedances of said electron device to doubly control the volume of the amplifier. 5

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