

Sept. 16, 1941.

R. A. BIERWIRTH

2,255,757

AUDIO FREQUENCY AMPLIFIER

Filed July 29, 1939

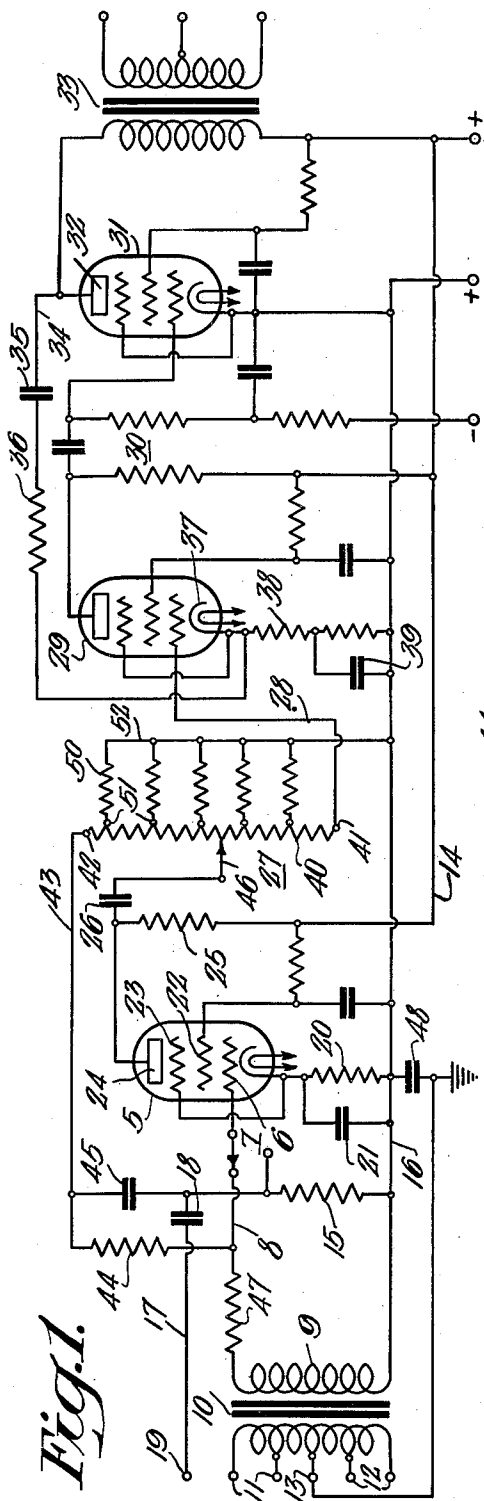


Fig. 1.

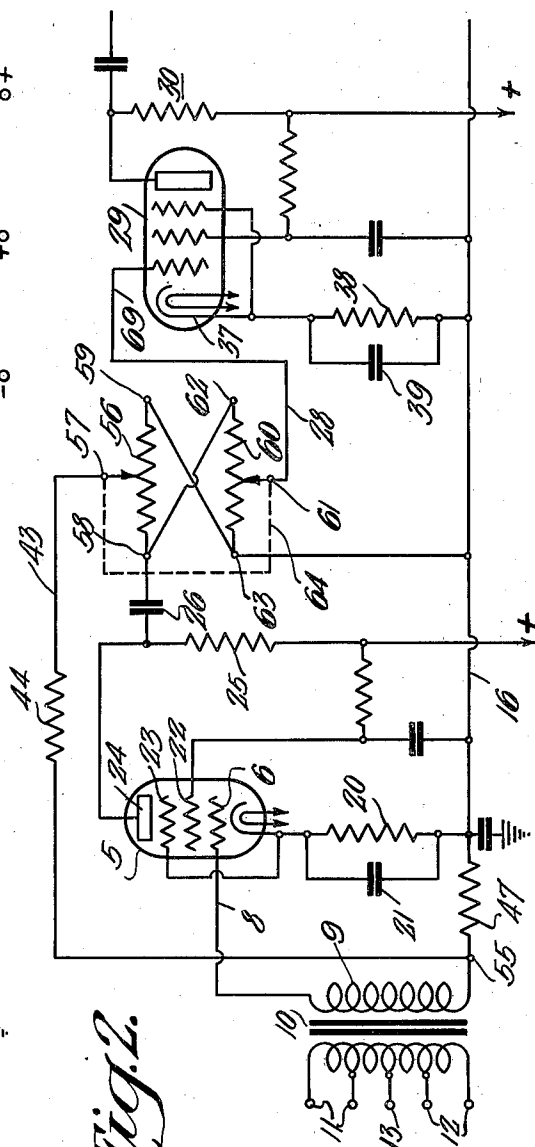


Fig. 2.

Inventor
Rudolph A. Bierwirth
 Attorney

UNITED STATES PATENT OFFICE

2,255,757

AUDIO FREQUENCY AMPLIFIER

Rudolph A. Bierwirth, Haddon Heights, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application July 29, 1939, Serial No. 287,306

5 Claims. (Cl. 179—171)

The present invention relates to audio frequency amplifiers, and has for its object to provide an improved volume control system therefor having a single control means for varying the signal attenuation in connection with one amplifier stage and the gain by inverse feedback on a preceding stage, whereby improved volume control of signals is obtained and overloading of said preceding stage in response to applied signals is minimized.

It is also an object of the present invention to provide a multi-stage audio frequency amplifier having means for variably attenuating signals in a plurality of stages by operation of a single control element in a coupling network between two of such stages providing control of the signal voltage amplitude applied to the input circuit of one stage and of an inverse feedback voltage to the input circuit of the preceding stage in predetermined relation, whereby signal distortion by overloading in said preceding stage is substantially prevented.

The invention will, however, be better understood from the following description, when considered in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing,

Figure 1 is a schematic circuit diagram of a multi-stage audio frequency amplifier provided with volume control means embodying the invention; and

Figure 2 is a similar schematic circuit diagram of a multi-stage audio frequency amplifier showing a modification of the invention.

Referring to Fig. 1, 5 is a first stage amplifier tube having a signal input grid 6 selectively connectable through a switch 7 to an input circuit 8 comprising the secondary 9 of a microphone input transformer 10 on the primary of which are provided suitable input tap connections indicated at 11, 12 and 13. The alternate connection provided by the switch 7 for the input grid 6 includes an input grid resistor 15 having a common cathode return circuit connection 16 with the secondary 9, and having an input circuit 17 coupled thereto through a coupling capacitor 18. A terminal 19 for the circuit 17 provides a connection for a crystal microphone (not shown).

Bias potential for the amplifier is provided by a cathode resistor 20 having a capacitor 21. The tube may be of any suitable type adapted for audio frequency amplification and in the present example is shown as a screen grid pentode having a screen grid 22, a suppressor grid 23 and

an output anode 24. The latter is connected to a positive anode potential supply lead indicated at 14, through an output or anode coupling resistor 25 and is coupled through a suitable coupling capacitor 26 to an attenuator network 27 in the input circuit 28 of a second stage amplifier tube 29. The tube 29 in turn is coupled through a suitable capacity coupling circuit or network 30 with a third stage amplifier tube 31 having an output anode 32 connected to an output coupling device 33.

The succeeding amplifier stages may be provided with inverse feedback, such as the amplifier tube 31 which is provided with an inverse feedback connection 34 comprising a capacitor 35 and series resistor 36, to the cathode 37 of the second stage amplifier tube 29 and supplies inverse feedback voltage thereto across a cathode resistor 38. A portion of the resistor 38 is provided with a bypass capacitor 39 for controlling the high frequency response by limiting the inverse feedback in the upper portion of the audio frequency range.

The coupling network 27 between the input circuit 28 of the second stage amplifier 29 and the output circuit of the first stage amplifier tube 5 is preferably in the form of a volume control potentiometer or attenuator device 40, connected at one terminal 41 to the input circuit 28 and at the opposite terminal 42 with a second feedback circuit 43. The latter circuit is provided with a branch connection for each of the input circuits 8 and 17, through impedance elements 44 and 45, respectively, for imparting a predetermined frequency characteristic to each branch of the feedback circuit, as will hereinafter appear.

A series resistor 47 is provided in the input network for the transformer 10, between the secondary 9 and the feedback connection to prevent overloading the signal source when the inverse feedback increases. This permits feedback to the grid 6 without loading the transformer secondary.

The attenuator network 27 is further provided with a variable control contact 46 adapted to be moved over the potentiometer element 40 between the terminals 41 and 42, the arrangement being such that as the contact 46 is moved in the direction of the terminal 42 a signal transmitted through the amplifier from the first stage to the second stage is increasingly attenuated in the input circuit of the second stage by reduction of the applied signal voltage to the input circuit

28 while, at the same time, the feedback current is increased through the feedback circuit 43.

Thus the input circuits 8 and 17 receive an increasing feedback potential which tends to reduce the gain in the first stage by reducing the signal amplitude therein thereby preventing overload of the grid 6. The feedback voltage reduces the signal applied to the grid 6 of the first stage by the amount of the feedback and thereby prevents the tube from overloading and from causing distortion in the presence of strong input signals from any source which may be coupled with the input terminals 19 or 11 and 12. The distortion produced by the tube is also reduced by the feedback.

As the volume control element 46 is moved in the direction of the terminal 41, an increasing signal voltage is applied to the input circuit of the second stage amplifier while at the same time the feedback current to the first stage is reduced proportionately. Thus in the presence of weak signals applied to the input terminals 19 or 11 and 12, requiring less signal attenuation in the volume control means, the feedback voltage on the first stage is also reduced and may be made substantially zero when a maximum gain is provided in the second stage, as, for example, when the contact 46 is moved substantially to the output terminal 41 and directly in connection with the input circuit 28 of the second stage. Under this condition, the signal on the first stage amplifier is relatively low so that there is substantially no distortion, and feedback is not required.

The attenuator network 27 is in the form of a variable ladder having resistors 50 connected with spaced tap points 51 on the main attenuator resistor 40 and connected together through a lead 52 with the cathode return circuit 16. With this arrangement, as is well known, the load on the output circuit of the tube 5 is made substantially constant over the full range of control movement of the contact 46.

In the circuit shown, the contact 46 on the attenuator or coupling network 27 provides a single control means for both the signal attenuation in the input circuit of the second stage by direct control of the signal voltage applied thereto and signal attenuation in the input circuit of the first stage by inverse feedback thereto, the inverse feedback being varied thereby in an opposite sense to the signal voltage variation. It has been found that with the volume and feedback control element 46 adjusted for minimum volume at the terminal 42 the signal attenuation between stages may be of the order of from 30-35 d. b. and with the feedback maximum and of the order of 15 d. b., a total signal attenuation of from 45-50 d. b. may be provided. The attenuation applied to the input circuit of the first stage by inverse feedback has been found sufficient to prevent overloading and distortion with a condition of operation providing maximum signal amplitude at the input terminals.

The attenuator or coupling network between two amplifier stages for conjoint control of gain by direct signal attenuation and inverse feedback may be arranged in the manner shown in Fig. 2, to which attention is now directed and wherein the same reference numerals are applied to like parts as in Fig. 1.

The first stage amplifier tube 5 is coupled to the input transformer 10 as in the preceding figure, with the series resistor 47 in the input circuit 8 at the low potential side thereof adjacent to the cathode connection at the negative

end of the bias resistor 20 and the inverse feedback lead 43 is connected through the series resisting limiter 44 to a terminal 55 on the grid end of the coupling resistor 47 between the last named resistors and the low side of the secondary 9 so that the feedback voltage is applied in series with the signal voltage to the input grid 6.

The feedback voltage is derived from a separate control element comprising a resistor element 56 connected in parallel between the cathode return circuit 16 and the output coupling capacitor 26 across the output plate resistor 25. The resistor 56 is of the variable type providing a potentiometer having a movable contact 57 connecting with the feedback lead 43, the arrangement being such that as the contact is moved from the high potential end 58 to the low potential end 59, the negative feedback voltage derived from the resistor 56 is reduced, thereby reducing the feedback current and the potential drop caused by the feedback current in the resistor 47.

Also connected in parallel with the output plate circuit resistor 25 of the first stage tube 5 is a second potentiometer device comprising a resistor element 60 and a movable contact therefor 61, the high potential terminal 62 of the resistor 60 being connected to the terminal 58 and the low potential terminal 63 being connected with the terminal 59 and the lead 16.

The contact 61 is connected to the input circuit 69 with the second stage tube 29 and operates to control the signal potential applied to the second stage as a volume control device. As the contact 61 is moved from the terminal 63 to the terminal 62 along the resistor 60, the signal voltage applied to the second stage amplifier 29 is increased from minimum to maximum.

The two contacts 57 and 61 are connected for continued operation as indicated by the dotted connection 64 in such a manner that the feedback voltage or current to the first stage and the signal voltage applied to the second stage amplifiers are varied in an opposite sense, one with respect to the other. Thus, assuming that the contacts 57 and 61 move in unison by continued operation from left to right and right to left, as shown in the drawing, movement to the right causes the inverse feedback voltage to be reduced and the signal voltage applied to the second stage to be increased in a predetermined relation to each other and substantially in the same manner as when the circuit of Fig. 1, except that the two potential controlling elements are connected in parallel instead of being included in one resistance or impedance element in the coupling network between the two stages.

The circuit of Fig. 1 has certain advantages in that the controlling element is simplified by being provided with a unitary controlling device, while in the circuit of Fig. 2, the two resistance elements 56 and 60 may be designed to have differing resistance characteristics. That is, in the case of rotary control devices, the change in resistance for the same range of movement in each device may be different and may differ over various portions of the control range of movement of the contact elements.

In any case, however, it will be seen from the preceding description that in a multi-stage amplifier, a desirable gain control characteristic may be provided by arranging the interstage coupling network between the first and second stages or between any two stages, if desired, for the simultaneous control of gain in one stage and the control of degeneration or inverse feedback in a

preceding stage, thereby controlling the gain in said preceding stage and preventing overload in the presence of strong signals in the said preceding stage.

In operation, this provides for a reduction in inverse feedback and an increase in the gain of the preceding stage as the applied signal falls off in amplitude by increasing the gain without overloading the first stage while the gain in the second stage is correspondingly increased in a certain predetermined relation to the increase in gain in the first stage.

Conversely, as the applied signal increases at the first stage to maintain the same output volume or signal amplitude, operation of the volume control element serves to apply an increasing inverse feedback to prevent overloading and to reduce the gain in the first stage simultaneously with a reduction in the gain of the second stage.

This operation is accomplished through the continued control of inverse feedback in the one stage and the control of the applied signal voltage to the second stage without involving a plurality of circuit elements and variable control devices.

I claim as my invention:

1. In an audio frequency amplifier comprising a plurality of cascade connected amplifier stages, the combination of an interstate signal attenuator network including a variable impedance element for controlling signal attenuation, an amplifier stage preceding said network, and an inverse feedback circuit for applying inverse feedback potentials to said amplifier stage, said circuit including said variable impedance element whereby said inverse feedback potentials are conjointly controllable with signal attenuation, and said variable impedance element comprising a tapped potentiometer resistor having an output grid connection at one end thereof and a feedback output connection at the opposite end thereof, and being further provided with a variable input potentiometer contact movable along said potentiometer resistor between said ends, thereby to vary the signal attenuation and the degree of inverse feedback in opposite sense, one with respect to the other.

2. In a multi-stage audio frequency amplifier, the combination of a variable signal attenuator network for controlling the amplitude of signals applied to one stage of said amplifier whereby the signal output of said amplifier may be adjusted to compensate for variations in input sig-

nal amplitude, means for controlling the gain of a preceding amplifier stage and preventing overload of said stage in response to said input signal variations comprising an inverse feedback connection to said preceding stage through said attenuator network whereby the inverse feedback energy and signal attenuation are conjointly controllable through said attenuator network, and means in said network for jointly controlling said inverse feedback and signal attenuation in opposite sense, one with respect to the other.

3. In an audio frequency amplifier, the combination of a first stage amplifier tube having a signal input circuit and a signal output circuit, a second stage amplifier tube having a signal input circuit, an attenuator network including a potentiometer resistor connected serially between said input circuits, and means providing a variable connection for said output circuit with said potentiometer resistor, thereby to provide conjoint control of inverse feedback to said first named input circuit and signal amplitude applied to said second named input circuit in opposite sense, one with respect to the other, whereby conjoint control of gain is provided in each of said input circuits and overloading of said first named input circuit in response to increased input signal strength is prevented.

4. In an inverse feedback multi-stage audio frequency amplifier, the combination of a first stage amplifier tube having a signal input circuit and a signal output circuit, a second stage amplifier tube having a signal input circuit and a variable attenuator network connected between said output circuit and each of said input circuits providing conjoint control of inverse feedback to said first named input circuit and signal amplitude applied to said second named input circuit in opposite sense, one with respect to the other.

5. In a multi-stage audio frequency amplifier, the combination of a signal attenuator network for one of said stages including a single variable attenuator element, an inverse feedback circuit for a preceding amplifier stage including said variable attenuator element, and means in said inverse feedback circuit for modifying the feedback action therethrough, and means in said network for controlling signal attenuation and inverse feedback in predetermined mutual relation to each other.

RUDOLPH A. BIERWIRTH.