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AMPLIFYING SYSTEM

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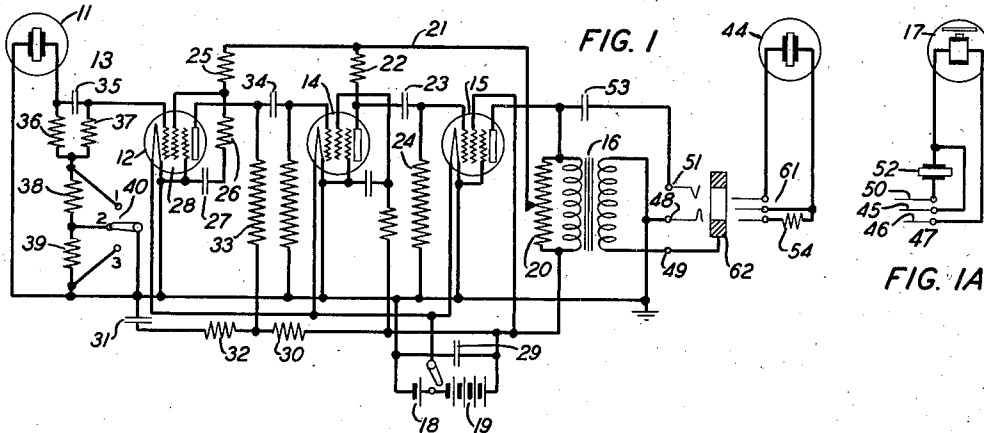


FIG. 2

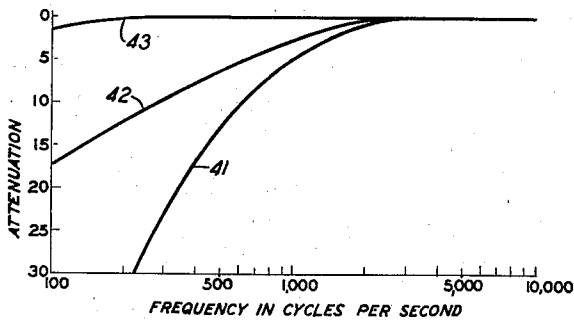


FIG. 3

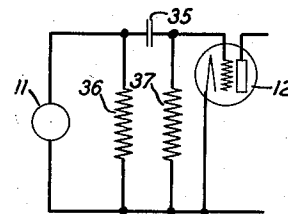


FIG. 4

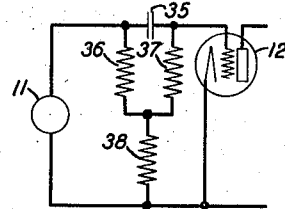
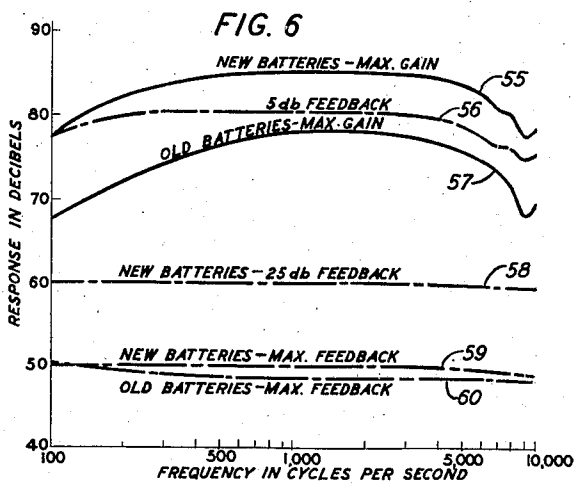
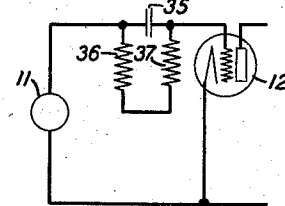


FIG. 5



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AMPLIFYING SYSTEM

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10 Claims. (Cl. 179-107)

This invention relates to amplifying systems and the object of the invention is an improved amplifier for use in portable apparatus such as audiphones.

In all battery operated amplifiers, particularly those with more than one stage, the amplifier gain changes due to the internal resistance of the plate battery increasing as the battery becomes discharged. This is caused by the signal voltages developed across the internal resistance of the battery being fed back both regeneratively and degeneratively to prior stages. The magnitude of these feedback voltages may easily be sufficient to cause the amplifier to oscillate in the case of excess regenerative feedback or for the gain to be reduced appreciably due to degenerative feedback. In the case of an audiphone amplifier, these effects are particularly troublesome because the weight limitation for such apparatus requires the use of miniature, short-lived batteries and does not permit connecting large capacity condensers across the plate battery to by-pass the feedback voltages.

Aside from the gain limitations of small portable amplifiers, audiphone users frequently experience difficulties in hearing intelligibly in noisy locations since the noise and the low frequency sound components overload the system and produce excessive distortion.

In accordance with an important feature of this invention, the volume level of the output is controlled by variable negative feedback so that for the lower sensitivities the feedback is greater thereby giving better quality of reproduction for those who have only slightly impaired hearing and who therefore are more likely to appreciate the better quality.

According to another feature of the invention, a circuit is provided for introducing a positive feedback proportional to the internal resistance of the battery so that the gain of the amplifier is substantially independent of the battery resistance or may, if desired, be made to increase or to decrease slightly as the battery is expended.

The pick-up microphone is connected to the amplifier through an adjustable network which gives the user a choice of several low frequency transmission characteristics according to his personal requirements or the particular characteristics of the sounds he wishes to hear. In noisy locations this network may be set to give a large amount of low frequency attenuation, thereby discriminating against low pitched noises and the lower sound frequencies of the voice which contribute but little to intelligibility. This pro-

cedure permits of greater amplification of the higher frequencies without overloading.

These and other features of the invention will be more clearly understood from the following detailed description and the accompanying drawing, in which:

Fig. 1 is a circuit diagram of an amplifying system according to the invention, using a crystal type receiver;

Fig. 1A shows an electromagnetic receiver adapted for use with the circuit of Fig. 1;

Fig. 2 shows the frequency response curves of the system;

Figs. 3, 4 and 5 show the elements of the coupling network connected in various ways to produce the several different low frequency responses; and,

Fig. 6 is a series of curves illustrating the use of feedback to control the volume and maintain a flat response and high gain independently of the aid of the battery.

Referring now to Fig. 1, the pick-up microphone 11 is preferably of the piezoelectric crystal type which, as is well known, is a high impedance device and may be connected directly to an amplifier without the use of a transformer. In this case, the microphone is coupled to the grid of the tube 12 by means of the adjustable network 13, the function of which will be described more in detail below. The tubes 12, 14 and 15 are resistance-capacity coupled and the output transformer 16 connects the tube 15 to the magnetic type receiver 17 of Fig. 1A in the conventional manner, or, alternatively, to the crystal receiver 44 in a novel manner to be described.

The battery 18 provides filament current for all three tubes and the battery 19 supplies the required voltages to the screen grids and plates through suitable resistors. The primary of the output transformer is shunted by the potentiometer 20 by means of which an adjustable portion of the output energy may be fed back negatively to the prior stages. Current flowing over the path including conductor 21, resistor 22, the condenser 23 and the resistor 24 will produce signal voltages across the latter resistor which are out of phase with the signal voltages from the tube 14 and therefore reduce the gain and correspondingly decrease the distortion. The resistor 22 also passes plate current for the tube 14, thereby making it unnecessary to provide a separate resistive connection to the battery for this purpose.

Another portion of the output signal energy flows through resistors 25 and 26 and condenser

27 to the negative side of the battery thereby impressing variable signal potentials on the screen grid 28 of the tube 12. These potentials are also in negative sense and therefore reduce the gain and distortion in all three stages. The resistor 25 and the conductor 21 also provide a direct current path for the screen current of the tube 12.

The elimination of the usual coupling condenser from the feedback path is particularly advantageous in portable apparatus such as audiotones where a bulk and weight should be kept as small as possible for, if used, such a condenser would have to be of large capacity to keep the amplifier stable at low frequencies.

As the battery resistance increases with use, the signal potentials developed across the battery terminals become appreciable and introduce other feedback at various points in the circuit, the most important of which are at the screen grid 28 of the tube 12 and the control grid of the tube 14. The feedback to the screen grid 28 will be negative, thereby reducing the gain of the amplifier even when the potentiometer 20 is at its lowest or zero feedback setting. The feedback potentials are impressed on the control grid of the tube 14 over a circuit including resistors 30 and 33 and the coupling condenser 34 in a positive or regenerative sense. This positive feedback would ordinarily be so much greater than the negative feedback to the screen grid 28 as to make the amplifier unstable but it is largely eliminated by the conventional filtering elements, condenser 29 and resistance 30 and condenser 31.

The resistance 30 and condenser 31, however, are not effective in reducing the negative feedback to the screen grid 28 and hence this feedback accentuates the normal loss of gain as the battery ages. To compensate for this undesirable effect, resistor 32 is connected in series with the filter condenser 31 across the plate circuit of the tube 12. The signal potentials existing across the battery resistance will build up across resistor 32 proportional potentials which are applied to the grid of the tube 14 through the condenser 34 as a positive feedback which is a function of the battery resistance. By proper choice of the value of resistor 32, this feedback may be made equal to, greater than or less than the loss of gain due to the aging of the battery, as desired. While an amplifier gain which is independent of battery resistance is very desirable, in practice it may be preferable to use slightly less positive feedback and permit the gain to decrease very slightly as the battery ages in order to avoid the possibility of ever obtaining enough over-compensation to make the system unstable.

The network 13, referred to above as providing the user with a choice of low frequency response characteristics, comprises a condenser 35, resistors 36 to 39 and a three-position switch 40. The problem of obtaining a high rate of attenuation of low frequencies in the input of this system is complicated by the very high impedance of the crystal microphone and the necessity for keeping the bulk and weight of the filter elements very small. Conventional inductance and capacity networks are entirely impractical since they are too large and heavy and in any case, to be effective, they would have to be placed in the low impedance output circuit where they would not protect the tubes against overloading. On the other hand, the more usual, simple resistance-capacity networks are unsuitable

since when designed for the required low frequency attenuation they also attenuate the middle frequencies excessively.

In order to obtain the required high attenuation at low frequencies only, with resistance-capacity elements in the input circuit, the network 13 has been designed as a two section filter with the transmitter 11 serving as the capacity element of the first section. The second section has the same attenuation as the first but different values of resistance and capacity so that the impedance variations of the transmitter with frequency do not affect the second section. By making the impedances of condenser 35 and resistance 37 of the second section high as compared with the impedances of the transmitter and resistance 36 of the first section, a maximum rate of cut-off approximating twice that of a single section is obtained. The two-section filter giving the high attenuation of low frequencies shown by curve 41 of Fig. 2 is used when the switch 40 is in position 1, in which case the network is effective as shown in Fig. 3.

When the switch is moved to position 2, the shunt impedance to ground through resistors 36 and 37 is increased by connecting in resistor 38 as shown in Fig. 4 thereby reducing the attenuation and giving the low frequency characteristic of curve 42. In position 3 the switch is cut out of circuit and the shunt impedances are greatly increased by the addition of the very high resistor 39 which, as shown in Fig. 5, virtually disconnects resistors 36 and 37 from ground so that they become merely a by-pass around the condenser 35. The condenser is therefore effectively removed from the circuit and the response becomes essentially flat over the usable portions of the frequency range, as shown by curve 43.

It will be observed from the curves of Fig. 2 that the filter network under the control of the simple single point switch 40 gives a choice of widely different low frequency characteristics without producing any appreciable change in the response of the system for the higher frequencies which are important from an intelligibility standpoint. In one very satisfactory network of this type the capacities of the microphone 11 and condenser 35 are 750 μ f and 250 μ f respectively, resistors 36 and 38 are each .25 Ω resistor 37 is 0.6 Ω and resistor 39 is 10 Ω . These values are, of course, merely illustrative and may be of other values depending on the particular transmitter and tubes used and on the degree of attenuation required.

The system is designed to be used with either a magnetic type receiver 17 or with a crystal receiver 44. When the magnetic receiver is used the contacts 45, 46 of the plug 47 are connected to the output terminals 48, 49 of the transformer 16 in the conventional manner. If desired, protection of the user from acoustic shock may be obtained by using a plug having a third contact 50 which connects one side of a limiting device 52 through terminal 51 and condenser 53 to the plate terminal of the primary winding of the transformer. The other side of the limiting device is connected to the negative terminal of the plate battery so that the device is effectively in shunt to the output of tube 15. This limiting device may be of any known type such, for example, as a non-linear resistor of the substance known as thyrite, the resistance of which decreases rapidly above a certain critical voltage. In cases where a more gradual limiting

action is preferred, it may be desirable to use some other known form of limiter such as a thermal device the resistance of which varies with its temperature.

The crystal receiver 44 is electrically equivalent to a small capacity of the order of $750\mu\mu\text{f}$ and its impedance over the frequency range of 100 cycles to 10,000 cycles per second therefore varies from about 20,000 ohms to 2 megohms. As is well understood in the art an output transformer suitable for use with a magnetic receiver is therefore impractical for use with a crystal receiver.

It has been shown that a constant K band-pass filter with a full shunt arm at the input will develop the maximum voltage across a condenser which is uniform over the frequency band. While such a network could be used to couple the crystal receiver to the amplifier this would involve a number of additional circuit elements which would not only increase the cost of the system materially but it would also add considerably to the bulk and weight of the system which would be a serious objection in the case of portable apparatus such as audiphones.

Applicant has found, however, that the transformers necessary for coupling the magnetic receiver to the amplifier may be used with the crystal receiver in such a manner as to simulate the effect of a constant K network. In this case a terminating resistance is connected across the secondary of the transformer and the crystal receiver is connected across the amplifier output through a suitable blocking condenser. For best results the transformer should have a very high leakage reactance but since this would ordinarily require a transformer of considerable bulk there are practical limitations on the leakage reactance in cases where the bulk and weight must be kept small. While the value of the terminating resistance will depend on the constants of the particular transformer used and other factors the optimum value can be readily determined by experiment. In one instance, for example, a very good response characteristic was obtained with a very small transformer suitable for use with the magnetic receiver with a secondary shunting resistance of 60 ohms.

In the circuit shown, when the plug 61 is inserted in the output jack one terminal of the crystal receiver is connected through contact 51 and the blocking condenser 53 to the plate of the output tube 15 and the other terminal is connected through contact 48 to the cathode of the tube. At the same time a resistor 54 of the proper value is connected across the secondary of the transformer through contact 48 and the sleeve 62 of the jack.

The shunting resistor 54 is, of course, not required when the magnetic receiver is used and because of the inherently limited output capacity of the crystal receiver, the voltage limiter is not required when the crystal is used. The resistor and limiter are, therefore, associated with the individual receivers and are preferably built into the respective receiver plugs as indicated so that the necessary circuit changes are made automatically when either receiver is connected for use.

Since the small crystal audiphone receiver is essentially a capacitative impedance a transformer of high leakage reactance may be used in the manner described to apply a constant voltage to other capacitative loads such, for example, as crystal or capacity type loud-speakers.

In cases where good low frequency response is important a slightly better characteristic may be obtained by connecting a suitable condenser in series with the resistor 54.

The advantages of this amplifier from the standpoint of high quality and sustained gain over the useful life of the battery are illustrated in Fig. 6. As shown by curve 55 when the batteries are new and the amplifier is operating at maximum gain, that is, with no negative feedback, the response is reasonably uniform from 100 to 10,000 cycles. This very large gain is very rarely, if ever, required, however, and as shown by curve 56, the response becomes much more nearly uniform when the output volume is decreased by only 5 decibels of negative feedback. The response characteristic is, of course, still further improved as more feedback is used and with 25 decibels feedback there is no perceptible variation of gain as shown by curve 58 but the output level is still ample for a large proportion of audiphone users.

Curve 57 shows the general configuration of the response curve for maximum gain when the batteries have deteriorated to a point where their voltage is only two-thirds of the new battery voltage. While this curve shows some reduction of low frequency response, this loss of gain is very much less than in prior audiphone amplifiers and the circuit shows no tendency to oscillate. It will also be understood that while curve 57 shows an appreciable loss of gain as compared with the gain when using new batteries, this is largely a matter of choice since it is quite feasible to use enough positive feedback to keep the gain practically constant over the whole range until the batteries are completely unfit for further use.

But even when the positive feedback used is not sufficient in itself to make the gain independent of the battery resistance at maximum gain, the gain and the uniformity of response with maximum negative feedback are affected only slightly by the increasing battery resistance as shown by curves 59 and 60.

While the various features of the invention have been described with particular reference to audiphones, it will be apparent that some of them are equally applicable to other apparatus within the scope of the following claims.

What is claimed is:

1. In an audiphone system, a pick-up microphone, a vacuum tube amplifier having input and output circuits, a telephone receiver connected to the output circuit, a volume control comprising a variable negative feedback path within the amplifier for progressively improving the transmission characteristic of the amplifier as its gain is reduced and a network connecting the microphone to the input circuit, said network having an adjustable low frequency attenuation whereby the low frequency output of the system may be regulated in accordance with the noise level at the microphone independently of the volume control.

2. An amplifier having a negative feedback path, a battery for the amplifier having an internal resistance which tends to increase with use and increase the negative feedback of the amplifier and means for introducing into the amplifier a positive feedback proportional to the internal resistance of the battery.

3. An amplifier comprising at least three vacuum tubes having input and output circuits connected in tandem, a source of power for the tubes

connected to the output circuit of the last tube, a path conductive to both signal and direct current from the output circuit of the last tube to the output circuit of the second tube, a screen grid in the first tube and a second path conducting both signal and direct current from the output circuit of the last tube to said screen grid.

4. An amplifier comprising a plurality of vacuum tubes each having an input and an output circuit connected in tandem, a battery for energizing the tubes and a negative feedback path extending from the output circuit of the last tube to the input circuit of one tube and conducting current from the battery to the output circuit of another tube.

5. In an audiphone system, the combination with a pick-up microphone having a predetermined capacity, a receiver, an amplifier connecting the microphone to the receiver and a source of current for the amplifier, of a resistance-capacity network interposed between the microphone and the amplifier and forming with the capacity of the microphone a filter of at least two sections for selectively attenuating low frequency currents.

6. An audiphone system according to the preceding claim in which the impedances of the second section of the filter are high as compared with those of the first section whereby the variations in the impedance of the microphone do not affect the impedance of the second section of the filter.

7. In an audiphone system, the combination with a crystal type microphone, a receiver and an amplifier having an input circuit connected to the microphone and an output circuit connected to the receiver, of a condenser serially connected in one side of the input circuit, two resistors connected in series across the condenser and resistance connected from the junction of the resistors to the other side of the input circuit and means for modifying the effect of the resistance on the input circuit.

8. In an audiphone, the combination with a crystal type pick-up microphone, a receiver and a vacuum tube amplifier connecting the microphone to the receiver and having a substantially uniform transmission characteristic, of a network for adjusting the response of the audiphone over a limited range of low frequencies without affecting the transmission of other frequencies connected between the microphone and the amplifier and comprising a series condenser, a resistance by-passing the condenser, a resistive shunt arm connected to an intermediate point on the resistance, and means for adjusting the effective resistance of the shunt arm.

9. In an amplifying system, the combination with a vacuum tube amplifier having input and output circuits, a pick-up microphone connected to the input circuit and an output transformer having a secondary winding and a primary winding connected across the output circuit, of a receiver having a capacitative impedance connected across the output circuit and a resistor connected across the secondary winding to form with the transformer a terminating network for developing across the receiver a high voltage which is substantially uniform over the frequency band transmitted by the amplifier.

10. In an amplifying system, an amplifier having input and output circuits, a pick-up microphone connected to the input circuit and a transformer having a secondary winding and a primary winding connected to the output circuit and means for selectively connecting the secondary winding to a magnetic receiver or the output circuit to a capacitative receiver and the secondary winding to a loading impedance proportioned to maintain the voltage across the capacitative receiver substantially uniform over the frequency band transmitted by the amplifier.

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