

Oct. 11, 1949.

M. E. ROSE

2,484,052

AMPLIFIER HEARING AID

Filed Aug. 3, 1946

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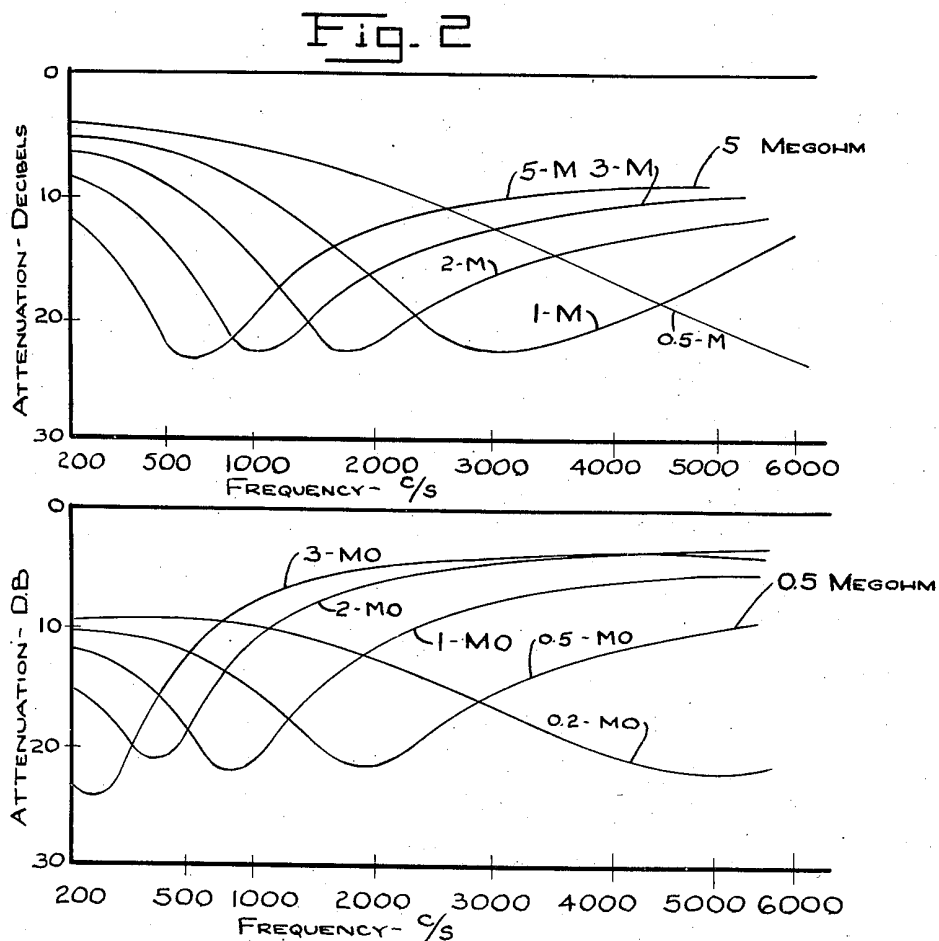
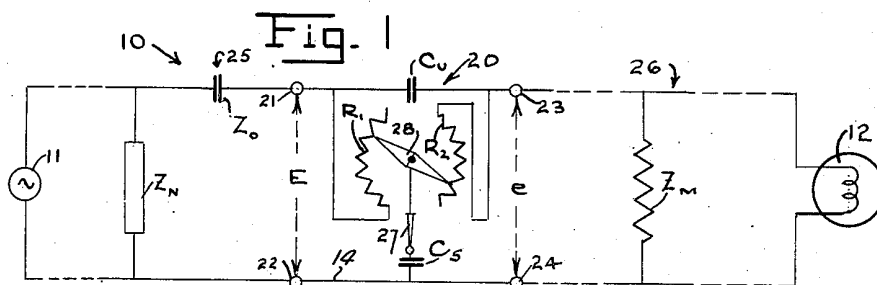


Fig. 3

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Fig. 5

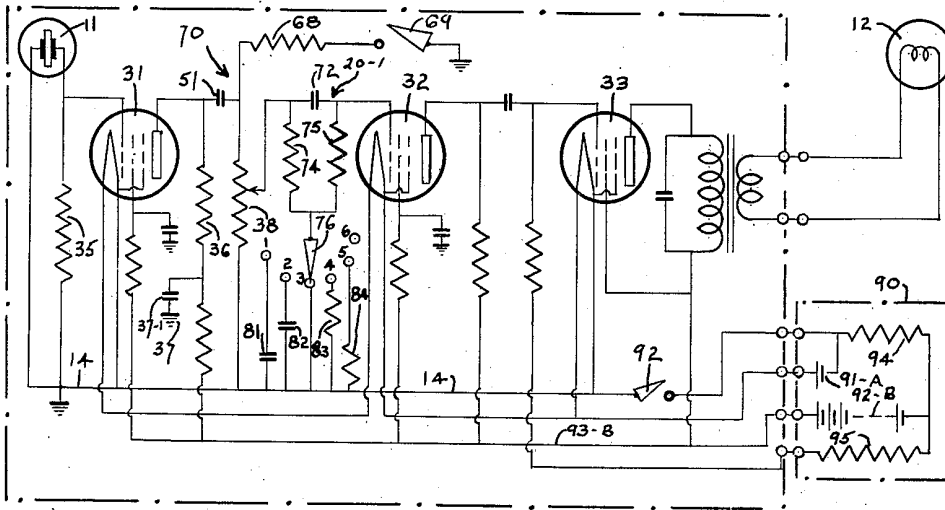
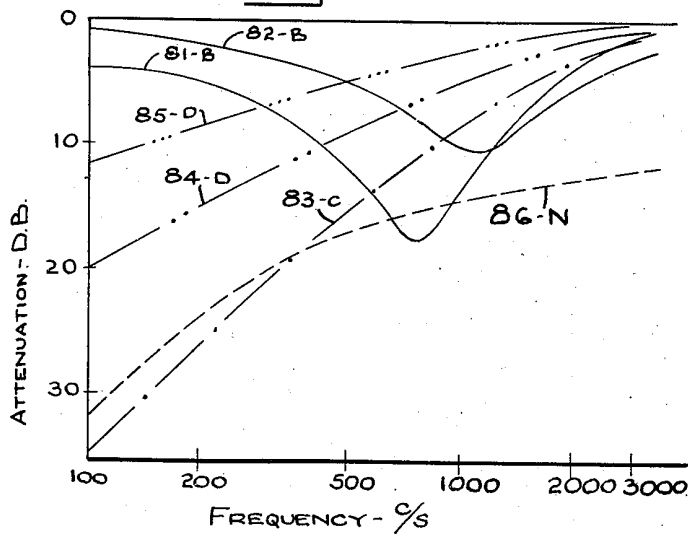


Fig. 5-A



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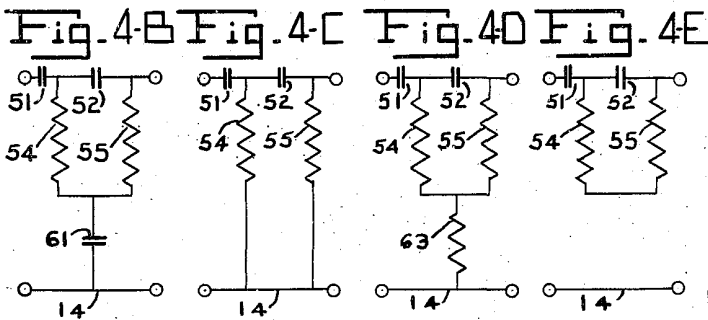
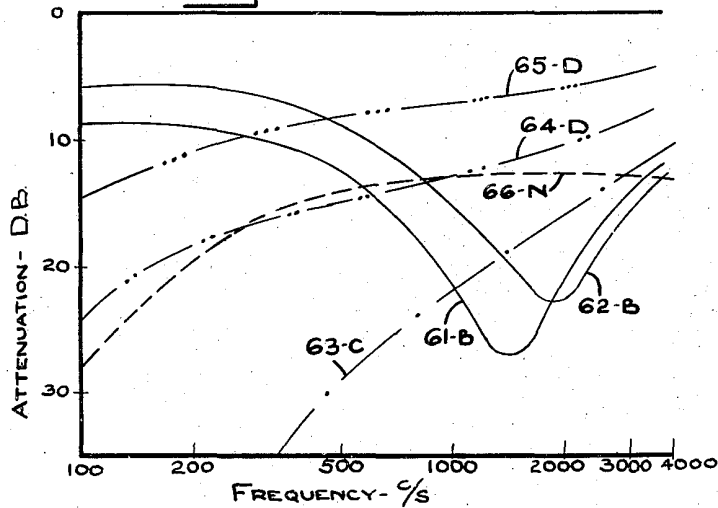
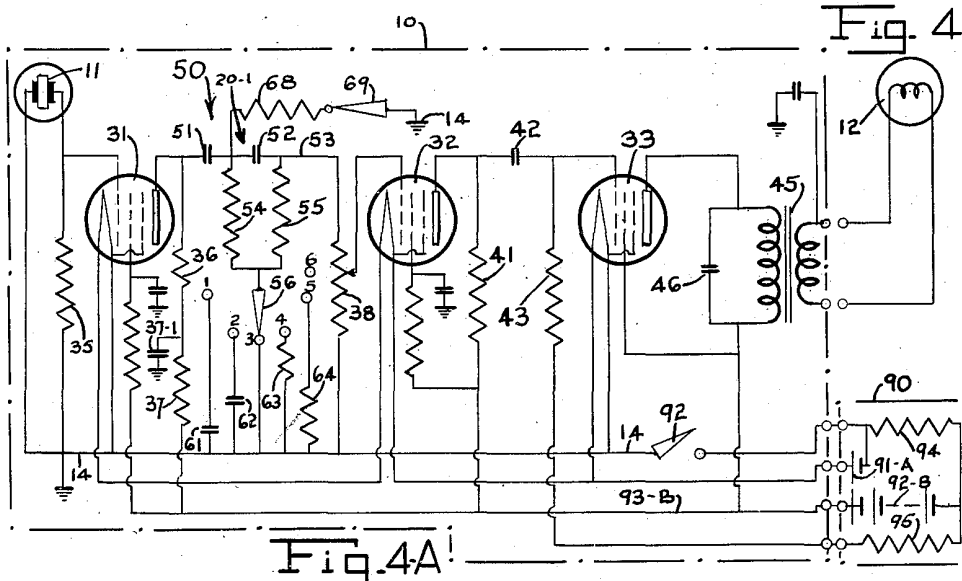
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AMPLIFIER HEARING AID

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6 Claims. (Cl. 179—171)

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This invention relates to hearing aids, and more particularly to electronic-amplifier hearing aids of the type which are small enough to be worn on the body of the user.

Among the objects of the invention is an improved electronic-amplifier hearing aid arrangement provided with selectively operable means for controlling the frequency response characteristics of said hearing aid so as to make it possible to selectively decrease the amplification in frequency regions in which excessive amplification would be detrimental to the hearing of the user, while securing the desired high amplification in the frequency regions by the character of his hearing impairment.

The foregoing and other objects of the invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings, wherein—

Fig. 1 is a simplified diagram of an electronic-amplifier hearing aid having a selective frequency response control arrangement exemplifying one form of the invention;

Figs. 2 and 3 are two curve diagrams each showing a series of curves illustrating the operation of two modified forms of a hearing aid amplifier arrangement exemplifying the invention;

Fig. 4 is a circuit diagram of one practical form of a hearing aid amplifier arrangement exemplifying the invention;

Fig. 4—A is a curve diagram showing a series of frequency response curves of the hearing aid of Fig. 4;

Figs. 4—B, 4—C, 4—D and 4—E show four different connections of the elements of the response control network for securing different responses by the operation of a single control member;

Fig. 5 is a circuit diagram of another practical form of a hearing aid amplifier arrangement exemplifying the invention; and

Fig. 5—A is a curve diagram showing a series of frequency response curves of the hearing aid of Fig. 5.

It is well known that many individuals having impaired hearing have a hearing loss limited to a restricted part of the frequency range and that a hearing aid designed to amplify the audible range with uniform frequency response characteristics has to be provided with response control means for selectively attenuating the amplification of the hearing aid output in the restricted part of the audio-frequency range in which the user's hearing is not impaired and ex-

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cessive amplification would disturb or even cause injury.

In the case of some individuals, it is desirable to attenuate the amplification of the hearing aid in the low-frequency part, in others in the high-frequency part, and in still others in an intermediate or mid-part of its frequency range. Accordingly, an ideal electronic amplifier hearing aid should make it possible to provide for a controllable attenuation over any specified part of the audio-frequency range which is important for intelligibility of speech, and this controllable attenuation should be fairly selective—that is, when providing attenuation in one part of the frequency range, the response in the other parts of the frequency range should not be excessively reduced or cut. The provision of a satisfactory wearable hearing aid meeting these requirements presents many problems, because the design of a practical hearing aid amplifier arrangement equipped with such selective attenuation or tone control network is subject to a number of controlling limitations. The attenuation control network should be simple and should require only a very small number of circuit elements occupying only very little space in the hearing aid housing. The network should be formed of resistances and capacity elements only and should not require any inductance coils. The circuit elements of the tone control network should be compatible with the other elements of the amplifier, required in order to secure the required amplifier gain and the required amplified signal output, and a D. C. path to ground must be provided in the load circuit of the network. Furthermore, the attenuation network should be controllable by a simple control element having preferably only a single control member, such as a switch. The small resistors and condensers available for such attenuation control network place an upper limit on the values of the resistances and on both upper and lower limits of their capacity values. The hearing aid amplifier must have means for effectively removing the tone control network so as to provide uniform amplification over the entire frequency range as required in the case of many individuals.

Many efforts have been made in the past to provide wearable electronic amplifier hearing aids which aim to meet at least part of the foregoing requirements. However, the best prior-art hearing aid amplifiers did not provide for selective attenuation of the amplifier in other than either in the high frequency part or in the low frequency part of the range, and in the latter

case they used a volume control potentiometer placed in the power output circuit between the power amplifier tube and the receiver.

The present invention makes it possible to provide an electronic amplifier hearing aid capable of delivering the required large output of good quality over the important, relatively wide part of the audible frequency range with two amplifier-gain stages and one power amplifier stage, while at the same time providing for selectively attenuating the transmission response characteristics of the hearing aid, not only in the low-frequency part of its frequency range, but also in the high-frequency and mid-frequency parts thereof.

Before describing a specific form of an electronic amplifier hearing aid exemplifying the invention, some of the principles underlying the invention will first be explained by reference to the simplified diagram of an electronic amplifier hearing aid shown in Fig. 1. It has a microphone 11 which picks up the sound transmitted through the air, and an amplifier circuit 10 through which is connected a receiver 12. The amplifier circuit 10 has a low potential side 14, which is usually formed by the common return lead to which the cathodes of the several amplifier tubes are connected, the other side of the amplifier being formed by the circuit sections through which the microphone 11 impresses its output on the control grid of the first amplifier stage and through which the output of each amplifier tube is successively impressed on the control grid of the next higher amplifier stage, and through the output of the power output tube on the receiver 12.

The microphone 11 may be of the conventional piezo-electric crystal type. Such crystal type microphone has a high impedance and may be connected directly to the input or control grid of the first high-gain amplifier tube, although it is usually desirable to connect across the terminals of such crystal type microphone, a relatively high grid resistance such as of 5 megohms. The receiver 12 may be either of the magnetic type, as indicated—in which case it is coupled to the output side of the power amplifier stage by a transformer; or it may be a crystal type receiver.

In general, a hearing aid circuit of the type shown in Fig. 1, and provided with two high-gain amplifier stages and one power output amplifier stage, may be readily designed for operation with uniform transmission characteristics over a frequency range important for a satisfactory hearing aid, namely, between about 300 to 4,000 cycles per second, and for delivering to the receiver the volume of sound required by individuals having severe hearing impairment.

According to one phase of the invention, the operating circuit of such electronic amplifier hearing aid is combined with a response control or attenuation network selectively operable to attenuate the response not only in the low-frequency part of its operating range, but also in the mid-part and high-frequency part of the frequency range.

Fig. 1 shows one form of response control network, generally indicated 20, connected in the operating circuit extending between the microphone 11 and receiver 12. The control network 20 constitutes a bridged T network, having at its input side two input terminals 21, 22, connected to the circuit section 25 of the amplifier 10, and at its output side two output terminals

23, 24, connected to a circuit section 26 of the amplifier 10.

The network 20 has a series capacitance section formed by condenser C_u connected in the generally high-potential side of the amplifier, a resistance circuit portion formed of two resistance elements R_1 , R_2 , connected parallel to the series capacitance circuit portion C_u , and a shunt capacitance C_s connected between the resistance portion of the network.

It can be shown that when a bridged T attenuation network, such as indicated at 20 in Fig. 1, has its input terminals connected to an electric energy source without any impedance, the ratio of the input voltage E applied to its input terminals to the voltage e delivered at its output terminals, or the attenuation A of the network, is given in db by the equation:

$$A = 20 \log \frac{E}{e} = 20 \log \left[\frac{(\alpha\lambda(1-\lambda)y-1)^2 + y(1+\alpha\lambda)^2}{(\alpha\lambda(1-\lambda)y-1)^2 + y} \right]^{\frac{1}{2}} \quad (1)$$

where

$$\alpha = \frac{C_s}{C_u}; \lambda = \frac{R_1}{R_1 + R_2}; x = 2\pi f(R_1 + R_2)C_u; y = x^2$$

It can also be shown that for an attenuation network of the type described in connection with Fig. 1, the frequency of greatest attenuation f_0 is given by the equation:

$$f_0 = \frac{1}{2\pi\sqrt{R_1 R_2 C_s C_u}} \quad (2)$$

To obtain good selectivity or discrimination, that is to secure the greatest difference in the level between points of maximum and minimum attenuation, the shunting condenser C_s must be considerably larger than the series condenser C_u . To obtain good selectivity in a hearing aid amplifier circuit, a bridged T network of the type described in connection with Fig. 1 should have a shunt capacity C_s of about ten times greater than C_u or larger, if possible, although in some cases it may be sufficient to make the shunt capacity only about five times greater than the series capacity of the network.

If the values of the two condensers C_s and C_u are chosen too small, the resistors R_1 , R_2 must be made unduly large in order to provide sufficient attenuation for frequencies below 1,000 cycles. The effectiveness of the attenuation network 20 in providing the desired attenuation, may be selectively removed by disconnecting the shunting condenser C_s from the resistances R_1 , R_2 , as by a switch 27 connected in the lead from the resistances R_1 , R_2 to the shunting condenser C_s . The discrimination of the network may be varied with a single control element—for instance, by making the two resistances R_1 , R_2 in the form of two rheostats provided with a common contact arm 23, so that by turning the arm 23, the value of the resistances R_1 , R_2 connected in the attenuation network may be varied to vary the discrimination or difference in the level between the points of maximum and minimum attenuation.

A practical form of such response network suitable for use in a hearing aid amplifier circuit of the type described above may be formed with the following condenser and resistance values:

Series condenser C_u , 10 micro-microfarads,
Shunt condenser C_s , 250 micro-microfarads,
Resistances R_1 , R_2 , variable in value between 5 megohms and $\frac{1}{2}$ megohm.

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If a response control network with the foregoing parameters has its input side connected to the voltage source through a capacitance series impedance Z_0 of 500 micro-microfarads and has its output terminals connected to an output load of 10 megohms, it will attenuate the input in the manner shown in Fig. 2, where the curves 5—M, 3—M, 2—M, 1—M, and .5—M indicate the attenuation in db for resistance values of 5 megohms, 3 megohms, 2 megohms, 1 megohm, and .5 megohm, respectively, used as resistors R_1 , R_2 , the attenuation being indicated with respect to the upper horizontal zero line of attenuation. In this circuit arrangement, the series capacitance input impedance Z_0 forms with the resistance R_1 and shunt capacity C_s the first section of a frequency selective attenuation filter, the series capacitance forming with the resistance R_2 and the shunt capacity C_s the second section of such filter.

A similar set of attenuation curves 3—MO, 2—MO, 1—MO, .5—MO, and .2—MO of Fig. 3 shows the attenuation obtained with resistances R_1 , R_2 of 3 megohms, 2 megohms, 1 megohm, .5 megohm, and .2 megohm, respectively, if the network parameters are modified by using a series condenser C_u of 40 micro-microfarads and a shunt condenser C_s of 700 micro-microfarads, while a resistance Z_m of 2 megohms is connected in shunt between the input side of the capacity Z_0 of 500 micro-microfarads and the ground lead 14.

It can be seen from Equation 1 that the correlation of the values of the attenuation to the frequency of maximum attenuation can be adjusted by changing the product of the resistances R to the capacitances C of the network, since by changing the resistances and the capacitances, the attenuation curves are shifted only to higher or lower frequencies corresponding to a decrease or an increase of the product of $R \times C$. The shape of the curves and the depth of the maximum attenuation do not change with such shifting of the curves.

For any value of the ratio of the shunting capacity C_s to the series capacity C_u , the discrimination may be improved by making the ratio of R_1 to the sum R_1 plus R_2 as large as possible, the maximum discrimination being obtained when the two resistances R_1 , R_2 are equal. If the attenuation is to be controlled only by a single switch or, in general, by a single control element, the maximum attenuation obtainable with a given set of circuit elements is not variable. However, by the addition of one more condenser in series with circuit connection to the series condenser C_u and a switching arrangement for eliminating the additional condenser, the maximum attenuation may be varied.

By providing an additional control element, it would be possible also to provide for variation of the maximum attenuation, for instance, by using the additional switch for connecting an additional condenser in series with the input side of the network 20 shown in Fig. 1.

As indicated by the curves of Figs. 2 and 3, some insertion loss is introduced by combining the hearing aid amplifier with the response control network. Thus, the network operating as shown in Fig. 2, with the setting of curve 0.5—M, for attenuating the high-frequencies, will introduce an insertion loss of 3 db at the low-frequency end. With the setting of curve 5—M, for cutting the low frequencies, it introduces an in-

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section loss of 7 db in the high-frequency part of the range.

In general, the factors of insertion loss, selectivity, and the frequency of maximum attenuation all depend on the circuit parameters in such a way that the optimum designs for various performance features are mutually exclusive. For example, if the network is designed to decrease insertion loss at high frequencies, it is necessary to increase all capacitance values. However, in order to secure the desired operating characteristics of the amplifier circuit at the low frequencies, the capacitances of the tone control circuit must not be too high. Accordingly, since it is desired to provide a tone control network with a single set of capacitance values which are to remain fixed, it is not possible to simultaneously eliminate all loss at low and high frequencies.

Notwithstanding the foregoing limitations, the response control network of the invention designed to meet these limitations lends itself for use in combination with a three-stage electronic amplifier hearing aid to provide selective attenuation of the frequency response either in the low part or mid-part or high part of the frequency range, while permitting removal of the network by a single control element for enabling the hearing aid to operate with a substantially level frequency response characteristic.

The control networks of the type described above in connection with Figs. 1 to 3 may be readily designed for use in connection with a three-stage electronic amplifier hearing aid so as to make it possible to attenuate the level by about 16 db either in the low-frequency part or the mid-frequency part or in the high-frequency part of the over-all frequency range. If the response network of the invention is designed to provide for attenuation greater than 16 db in a selected part of the frequency range, this would result in an undesirable increase of the insertion loss.

The response network of the invention is connected in the hearing aid amplifier circuit so that the voltage of the energy source is impressed on the input terminals of the network through an input condenser, and the impedance of the input condenser makes it necessary to make the shunt condenser C_s as small as possible in order to avoid undue loss at low frequency. Since the series condenser C_u must be still smaller than the shunt condenser C_s , it is necessary to compromise by choosing the value of the shunt condenser C_s so that it is not too large compared to the series condenser C_u and yet keep it small in relation to the value of the input condenser.

Good results are obtained if the network is used with a series input capacitance of about 500 micro-microfarads. An appreciable increase in the value of such input capacitance would give even better results, because it would make possible a better impedance match between the energy source and the response control network.

The load impedance Z_m should be fairly large, such as a resistance of 10 megohms. However, because of other limitations, it is impractical in most cases to increase the load resistance above about 5 megohms.

If a response tone control circuit operating with high impedance elements is combined with the input side of the first high-gain stage of a hearing aid amplifier, a great deal of disturbing noise appears in the output of the hearing aid. On the other hand, difficulties are also encoun-

tered if tone control networks and volume control circuits are combined with circuit parts associated with the power output stage of the hearing aid amplifier.

In a practical electronic amplifier hearing aid based on the principles of the invention, these difficulties are avoided by placing all elements of the response control network and of the volume control between the output side of the first-gain amplifier tube and the input side of the second-gain amplifier tube.

Fig. 4 shows diagrammatically one practical form of an electronic amplifier hearing aid operating with three amplifier stages and equipped with a response control arrangement in accordance with the principles of the invention.

The amplifier circuit which connects the microphone 11 to the receiver 12 has three amplifier sections—namely, a first high-gain amplifier section using tube 31, a second high-gain amplifier stage using tube 32, and a power output amplifier stage using tube 33, the three tubes shown all being pentodes. The amplifier circuit has a common low-potential or grounded side formed by the conductor 14 to which one terminal of each of the cathodes of the three tubes 31, 32 and 33 is connected. The microphone 11, which, as described, may be of the crystal type, is coupled to the control grid of the first amplifier tube 31 across an impedance limiting resistance 35. The amplified microphone input is impressed by tube 31 on its output circuit including a load resistor 36 and a coupling resistor 37 which is by-passed by a by-pass condenser 37-1. The output voltage developed across the load resistance 36 is impressed through an attenuation control network, generally designated 50, on a variable potentiometer resistance 38 which serves as the volume control of the hearing aid.

A component of the voltage impressed on the potentiometer resistance 38 is impressed by a tap thereof on the control grid of the second high-gain amplifier tube 32. The output of the tube 32 is impressed on a load resistance 41, and the voltage developed across it is supplied through a coupling condenser 42 across the grid input resistor 43 to the control grid of the power amplifier tube 33.

The elements of the amplifier unit are housed in a small, flat, compact casing indicated by the dash-dot line 10, the operating elements of the hearing aid being operated by energy supplied by a battery assembly 90. The battery assembly 90 has mounted therein an A-battery 91—A which supplies heating current to the filamentary cathodes of the several tubes 31, 32 and 33 through an energizing circuit including a switch 92 which is closed whenever the hearing aid has to be operated.

The relatively high direct-current voltage required for the plate or anode circuits of the amplifier tubes, is supplied by a B-battery 92—B through lead 93—B to which the plate circuits and the screen grid circuits of the several tubes are suitably connected so as to impress on the plates and screen grids the proper positive operating voltages. The low-potential side of the B-battery 92—B is connected in a conventional way to the cathode return lead 14 through a series resistance 94 so as to develop across it a bias voltage which is impressed through a circuit including a resistor 95 and the grid resistor 43 on the control grid of the power amplifier tube 33 so as to cause it to operate as a Class A amplifier.

The power amplifier output tube 33 delivers the amplified output to the receiver 12 through a conventional coupling circuit formed by a coupling transformer 45 having a condenser 46 connected to the primary side of the transformer.

As stated above, the response control network 50 is placed in the circuit section of the amplifier through which the output side of the first high-gain amplifier tube is connected to the input side of the second high-gain amplifier tube 32. The response control network comprises two series condensers 51, 52 connected in the high-potential side 53 of the amplifier section extending between the two tubes 31, 32, and resistors 54, 55 connected between two terminals of the condenser 52 and one terminal of a multi-positioned switch 56 which may be actuated to any one of its six contact positions 1, 2, 3, 4, 5 and 6.

When the switch 56 is in either one of the positions 1 or 2, it connects either the condenser 51 or the condenser 52 to the circuit elements 51, 52, 54, 55, to form a network shown in the simplified form of Fig. 4—B, which operates as a response control network of the type explained above in connection with Fig. 1.

When the switch 56 is in position 3, it connects the two resistance elements 54, 55 directly to the low-potential side 14 of the circuit section so that they form a network of the type shown in Fig. 4—C.

When the switch 56 is in either position 4 or 5, it connects the common terminal of the two resistance elements 54 and 55 to either one of the shunt resistors 63, 64 so as to form with the other circuit elements a network shown in simplified form in Fig. 4—D.

When the switch 56 is in position 6, it opens all shunt circuit connections and establishes the circuit connections shown in simplified form in Fig. 4—E.

The elements of the frequency control network are so chosen and designed that when the switch 56 is either in position 1 or 2, in which it connects them into the network shown in Fig. 4—B, the condenser elements 51 and 52 of the network, with the two resistances 54 and 55 and the shunt condenser C_s connected thereto, form a two-section filter, each section successively attenuating the input to the network to bring about the required large attenuation in the desired part of the frequency range. Thus, with the network connections shown in Fig. 4—B, the series condenser element 51 forms with the resistance element 54 and shunting condenser C_s the first filter section, which delivers the attenuated output to the second filter section formed by the second series condenser 52 in combination with the resistance 55 and the shunting condenser C_s , so as to secure with the two filter sections the required high attenuation of the response in the desired part of the frequency range.

In Fig. 4—A the response curves 61—B and 62—B show the attenuation obtained by the control network 50 when the control switch 56 is either in position 1 or 2, thereby establishing a network of the type shown in Fig. 4—B, the upper horizontal zero axis representing the response of the hearing aid when the switch 56 is in position 6, in which the hearing aid amplifier is operated with practically flat frequency response characteristics over the range between 300 and 3,500 cycles. In a satisfactory network 50 for securing such response control with a hearing aid,

the circuit elements of the network had the following condenser and resistance values:

Condenser 51	-----microfarads--	.0005
Condenser 52	-----micro-microfarads--	50
Resistance 54	-----megohms--	56
Resistance 55	-----do-----	56
Shunting condenser 61	-----micro-microfarads	1,000
Shunting condenser 62	-----do-----	500

In order to enable those skilled in the art to readily practice the invention, and without in any way limiting its scope, there are given below the other circuit constants of the circuit elements between which the attenuation network 50 was connected:

Load resistance 36	-----megohms	1.5
Coupling resistance 37	-----do--	.5
By-pass condenser 37-1	-----microfarads	.03
Volume control resistance 38	-----megohms	5

According to the invention, the response control network of the type described above and having only a single manually-operated control element in the form of switch 56, is also utilized to provide in the switch positions 3, 4 and 5 additional network connections for assuring selected degrees of more or less large attenuation in the low-frequency part of the frequency range of the type required in a hearing aid. Thus, in cases which require a high rate of attenuation of the low frequencies, it is merely necessary to actuate response control switch 56 to position 3, in which it establishes the network connections shown in Fig. 4—C at which the two condensers 51, 52 operate in conjunction with the two shunt resistances 54, 55 as two sections of a filter which, in the successive filter sections, is very effective in cutting the low-frequency part of the response, in the manner indicated in Fig. 4—A by curve 63—C. By moving the switch from position 3 to either of positions 4 and 5, for establishing the network connections shown in Fig. 4—D, there is provided a choice of two further, different low-frequency response cutoff characteristics, indicated in Fig. 4—A by the curves 64—D and 65—D. In one very satisfactory, practical tone control system of a hearing aid of the foregoing type, resistance 63 of .22 megohm and resistance 64 of .56 megohm were used in order to provide operation with the response control curves 64—D and 65—D, respectively.

An amplifier hearing aid provided with a tone control network of the type described above may be combined with additional auxiliary response control means for enabling the user of the hearing aid to reduce the overall gain of the hearing aid and also provide greater discrimination against low pitched sounds when he is in a noisy place, while retaining the desired frequency discriminating attenuation established by a given setting of the selective response control network of the type explained above in connection with the network 50.

Thus, in the case of the hearing aid of Fig. 4, the desired reduction in gain and greater discrimination in the low frequency part of its operating range may be obtained by connecting a resistance element 68 in shunt between the input side of the series capacity element 52 and the grounded side 14 of the amplifier circuit, a switch 69 making it possible to connect or disconnect the additional resistance 68 from the network circuit.

In Fig. 4—A, curve 66—N represents the attenuated response obtained by connecting resistance 68 to the network circuit while the selector switch 56 is in position 6 in which the hearing aid operated with a substantially flat frequency response indicated by the horizontal upper zero axis of Fig. 4—A. If the response selector control switch 56 is in any of its other positions 1 to 5, the hearing aid will operate not only with the attenuated response indicated in Fig. 4—A by curve 66—N, but with an additional frequency discriminating attenuation superposed thereon, as indicated by the attenuation response curves 61—B to 65—D explained above.

It should be noted, the selectively settable response-control network secures the desired selective lowering of the amplifier gain without being part of a regenerating or degenerating circuit portion of the two amplifier stages between which it is connected.

In Fig. 5 is shown an electronic amplifier hearing aid similar to that of Fig. 4 which shows another way in which a response control network may be combined with the circuit section extending between the first and second gain amplifier tubes. The hearing aid arrangement of Fig. 5 has a microphone 11, a receiver 12 and a three-stage amplifier operating with two gain tubes 31, 32 and an output tube 33 connected to operate in a manner generally similar to that described in connection with Fig. 4.

The hearing aid arrangement of Fig. 5 is modified, however, by supplying the amplified output of tube 31 which is developed across the load resistance 36 through a series condenser element 51 directly to the volume control potentiometer resistance 38 of the relatively high resistance value of about 5 megohms. A tone control network 20—1 generally similar in configuration to the network 20 of Fig. 4 is connected between the volume control resistance 38 and the control grid of the second amplifier tube 32, the elements of the control network 20—1 being so chosen and proportioned as to assure that in all positions of the network control switch 56, the network elements will provide the requisite grid resistance path between the control grid of tube 32 and the grounded return conductor 14.

The network 20—1 is shown formed with a series capacitance 72 connected in series between the tap of the potentiometer 38 and the control grid of tube 32, the network including the additional resistance elements 74, 75 arranged to be selectively connected through the single control switch 76 either to one terminal of the shunt capacity 81 or shunt capacity 82 in switch positions 1 and 2 or to one terminal of resistances 83, 84 in switch positions 4 and 5 or directly to the ground lead 14 in position 4, in a manner analogous to the network control arrangement of Fig. 4.

By placing the elements of the response control network 20—1 between the relatively large volume control resistance 38 and the control grid of the second gain tube 32, the elements of the network may be designed to exhibit a much greater resistance than when used in the manner shown in the hearing aid of Fig. 4. As a result, the frequency control network 20—1 introduces a smaller insertion loss in the amplifier although it is able to supply the same selective frequency discriminating attenuation as that of Fig. 4.

The elements of the frequency control network 20—1 are so chosen and designed in relation to the series capacitance 51 and potentiometer resistance

38 as to cooperate therewith as a two-section filter network in a manner analogous to that described for the corresponding elements of Fig. 4. Thus, when the switch 76 is in position 1 in which it established network connections analogous to those shown in Fig. 4—B, the series condenser 51 will form in conjunction with the resistor 74 and the shunt condenser 81 one section of an attenuation filter network, the attenuated output of which is further attenuated by the second section of the filter network formed by the series condenser 72 in conjunction with the resistor 75 and the shunt condenser 81.

The response control network of Fig. 5 may also be combined with additional auxiliary gain and frequency control means in the form of a resistor 68 selectively connected between the input side of the network 20—1 and the ground by a switch 69, in a manner analogous to that described in connection with Fig. 4.

A very satisfactory network arrangement 20—1 for securing with a hearing aid of the type described in connection with Fig. 5 selective frequency discriminating attenuation of the response in the manner indicated by the curves of Fig. 5—A, may be obtained with the network elements of the following values:

Condenser 51	microfarad	.0005
Condenser 72	micro-microfarads	25
Resistance 74	megohms	3
Resistance 75	do	3
Shunting condenser 81	micro-microfarads	200
Shunting condenser 82	do	100
Shunting resistance 83	megohms	.7
Shunting resistance 84	do	2.2
Volume control resistance 38	do	5

In Fig. 5—A, curves 81—B and 82—B show the frequency discriminating attenuation response with a response control network having the foregoing constants and the selector switch 76 either in positions 1 or 2 respectively, while the auxiliary switch 69 is open, and curves 83—C, 84—D, 85—D show the frequency selective attenuation response obtained under such conditions when the switch 76 is in positions 3, 4 or 5 respectively, the substantially flat zero response of Fig. 5—A being obtained when the selector switch 76 is in position 6, while the auxiliary switch 69 is open. In an analogous manner, curve 86—N of Fig. 5—A shows the attenuation response when the auxiliary switch 69 is closed and the response selector switch 76 is in position 6.

By connecting the response control network 20—1 directly to the control grid of the second amplifier stage, and connecting it to the output side of the preceding high gain amplifier tube through the high resistance of the volume-control potentiometer 38, the circuit of the elements of the network may be designed so that they all present to the load circuit of the first amplifier stage such high impedance at frequencies which are not attenuated by the network as to prevent substantial attenuation of the response in the parts of the frequency range in which full amplification is desired. This is illustrated by comparing the attenuation curves of Fig. 4—A, obtained with the hearing aid amplification circuit of Fig. 4 in which the volume control potentiometer resistance 38 is connected between the attenuation network 20—1 and the grid of the second amplification tube 32. Thus, as shown in Fig. 5, when the hearing aid amplifier of Fig. 5 operates with a setting which produces the at-

tenuation indicated by curve 81—B, the response at 3,000 cycles is reduced only about 2 db, and in the low frequency end only about 4 db. Similarly, when the hearing aid circuit of Fig. 5 operates with a setting which produces the attenuation indicated by curve 83—C in Fig. 5—A, the response at about 3,000 cycles is reduced only about 2 db. The improved performance obtained with the hearing aid amplifier circuit of Fig. 5 is due to the fact that by connecting the high resistance volume control potentiometer 38—having, for instance, a resistance value of 5 megohms—the first amplifier stage operating with a sub-miniature pentode gain tube 31 may be readily designed to operate with a gain of at least 25 db when used with a D. C. power supply battery supplying a relatively low voltage, such as 20 to 30 volts only.

It is understood, of course, that the values of the various constants of the circuit elements given above are merely illustrative and they may have other values depending on the type and arrangement of the elements and the degree of discriminative attenuation required.

The features and principles underlying the invention described above in connection with the specific exemplifications, will suggest to those skilled in the art many other modifications thereof. It is accordingly desired that the appended claims be construed broadly and that they shall not be limited to the specific details shown and described in connection with exemplifications thereof.

I claim:

1. In a hearing aid worn on the body of the user in which the amplified output of a microphone is supplied to a receiver; an amplifier circuit having at least two succeeding high-gain amplifier stages for amplifying a voltage input with a predetermined normal gain over a predetermined relatively wide audio-frequency range; a network having an input side and an output side arranged to be connected between said two stages for selectively lowering the gain over a limited part of said frequency range; said network being free of regenerating and degenerating elements of said amplifier stages; said network including a series circuit portion including a series capacitance connected in one circuit side of said amplifier circuit; a resistance circuit portion including a resistance connected across said series capacitance; said network including a plurality of shunting elements of different impedance characteristics arranged to be selectively connected between said resistance circuit portion and the other opposite-polarity side of said amplifier circuit; at least one of said shunting elements being formed of a shunting capacitance at least three times greater than said series capacitance for lowering the response in a mid-frequency part of the frequency range, and at least one of said shunting elements being formed of a resistance for lowering the low frequency gain; a volume control resistance connected in shunt to the amplifier circuit portion extending between said two stages; and control means including a single control member selectively movable to different positions in which different of said shunting elements are connected to said resistance circuit portion, said control member being also movable to an additional position in which said resistance circuit portion is directly connected to said other circuit side and to a further position in which said resistance circuit portion is disconnected from said other circuit side.

2. In a hearing aid worn on the body of the user in which the amplified output of a microphone is supplied to a receiver: an amplifier circuit having at least two succeeding high-gain amplifier stages for amplifying a voltage input with a predetermined normal gain over a predetermined relatively wide audio-frequency range; a network having an input side and an output side arranged to be connected between said two stages for selectively lowering the gain over a limited part of said frequency range; said network being free of regenerating and degenerating elements of said amplifier stages; said network including a series circuit portion including a first series capacitance and a second series capacitance connected in one circuit side of said amplifier circuit; a resistance circuit portion including a resistance connected across said second series capacitance; said network including a plurality of shunting elements of different impedance characteristics arranged to be selectively connected between said resistance circuit portion and the other opposite-polarity side of said circuit for lowering the response in a mid-frequency part of the frequency range, and at least one of said shunting elements being formed of a resistance for lowering the low frequency gain; at least two of said shunting elements being formed of two different shunting capacitances, each of which is at least three times greater than the series capacitance across which said resistance circuit portion is connected, and one of said shunting capacitances being at least twice greater than the other of said shunting capacitances for selectively lowering the gain in a mid-frequency part of said frequency range; at least one of said shunting elements being formed of a resistance element for selectively lowering the gain in the low frequency part of said frequency range; a volume control resistance connected in shunt to the amplifier circuit portion extending between said two stages; and control means including a single control member selectively movable to different positions in which different of said shunting elements are connected to said resistance circuit portion; said control member being also movable to an additional position in which said resistance circuit portion is directly connected to said other circuit side and to a further position in which said resistance circuit portion is disconnected from said other circuit side.

3. In a hearing aid worn on the body of the user in which the amplified output of a microphone is supplied to a receiver: an amplifier circuit having at least two succeeding high-gain amplifier stages for amplifying a voltage input with a predetermined normal gain over a predetermined relatively wide audio-frequency range; a network having an input side and an output side arranged to be connected between said two stages for selectively lowering the gain over a limited part of said frequency range; said network being free of regenerating or degenerating elements of said amplifier stages; said network including a series circuit portion including a series capacitance connected in one circuit side of said amplifier circuit; a resistance circuit portion

tion including a resistance connected across said series capacitance; said network including a plurality of shunting elements of different impedance characteristics arranged to be selectively connected between said resistance circuit portion and the opposite-polarity other circuit side of said amplifier circuit; at least two of said shunting elements being formed of two different shunting capacitances, each of which is at least three times greater than the series capacitance across which said resistance circuit portion is connected, and one of said shunting capacitances being at least twice greater than the other said shunting capacitances for selectively lowering the gain in a mid-frequency part of said frequency range; at least two of said shunting elements being formed of resistance elements and one of said resistance elements having a resistance of at least twice as great as the other of said resistance elements for selectively lowering the gain in the low frequency part of the frequency range; a volume control resistance connected in shunt to the amplifier circuit portion extending between said two stages; and control means including a single control member selectively movable to different positions in which different of said shunting elements are connected to said resistance circuit portion; said control member being also movable to an additional position in which an intermediate part of said resistance circuit portion is directly connected to said other circuit side and to a further position in which said resistance circuit portion is disconnected from said other circuit side.

4. In an amplifier circuit as defined in claim 1, in which a volume control resistance is connected in shunt to the input side of the network, said volume control resistance having a resistance which is at least of the order of the shunting resistance presented by the elements of said net-work connected by said control member in shunt to said volume control resistance.

5. In an amplifier circuit as defined in claim 2, in which a volume control resistance is connected in shunt to the input side of the network, said volume control resistance having a resistance which is at least of the order of the shunting resistance presented by the elements of said net-work connected by said control member in shunt to said volume control resistance.

6. In an amplifier circuit as defined in claim 3, in which the resistance of said volume control resistance is at least of the order of the shunting resistance presented by the elements of said net-work connected by said control member in shunt to said volume control resistance.

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