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ACOUSTIC APPARATUS

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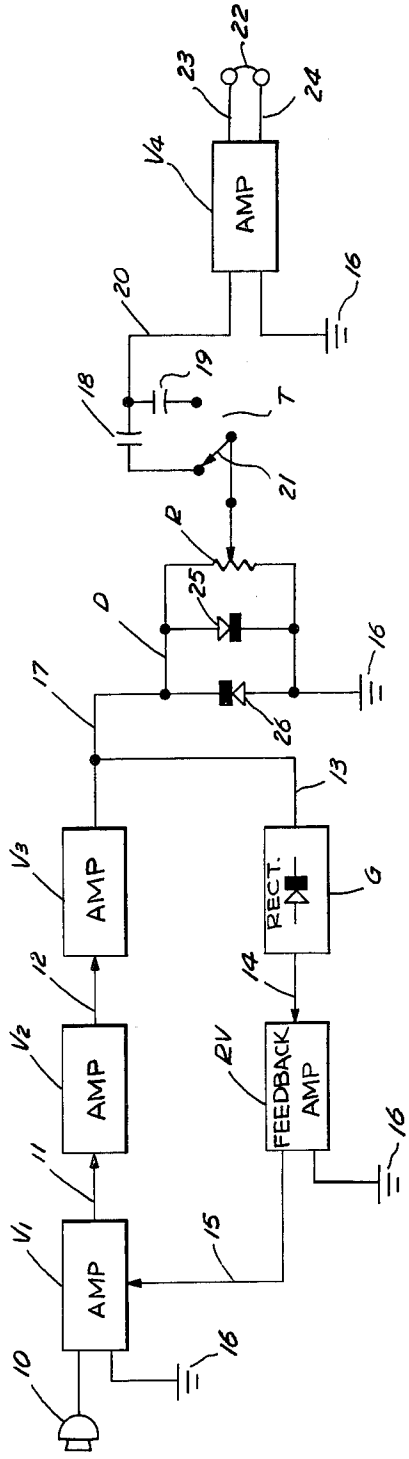


FIG - 1

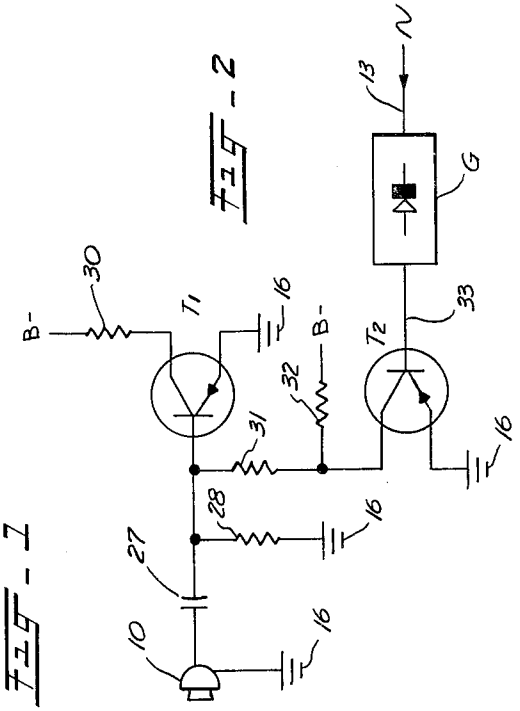


FIG - 2

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This invention relates to the field of acoustic apparatus and more particularly to the field of hearing aid amplifier circuits.

For persons who have experienced a hearing loss because of a damaged nerve system a problem is generally created where the threshold of hearing of the ear is quite near the threshold of discomfort for an ear which has not been damaged and this threshold sometimes shifts to lower sound pressure values. The hearing of such a person therefore often has a very restricted dynamic range, that is, the range between volume or sound pressures that are fairly audible and those that cause discomfort is relatively limited or quite narrow. For problems of this type, the correction of such hearing affliction is therefore rather difficult. Should the patient be supplied with a regular, linearly amplified hearing aid and adjust it so the threshold of discomfort of the patient can not be exceeded, then the low level sounds will be lost and if the amplification is increased so that low level sounds can be heard, then the loud sounds or noises when amplified exceed the threshold of discomfort by an appreciable amount and the patient feels a sense of pain rather than a sense of sound.

One attempt at eliminating the above mentioned problem is to make use of a "peak-limiting" circuit which limits the amplitudes of the previously amplified signals. An example of such a circuit would be one in which upon receiving a signal of a given amplitude, the amplification of a particular output stage would no longer operate linearly and all amplitudes going beyond a predetermined point would be cut off. This method makes use of the non-linearity characteristic which may be found in most transistor amplifier stages. This type of circuit does offer great simplicity with a relatively small number of components. However, a great disadvantage of this circuit is that it does not provide a regulation but only a limitation on the input signals and therefore cause appreciable distortion. The only advantage gained by this circuit then is that the pain level or threshold of discomfort is not exceeded by the input signals but the intelligibility of such signals is completely lost.

Another attempt at solving the problem outlined above will now be set forth. In this particular circuit, a portion of the signal voltage is taken from the final stage of the hearing aid, and after rectification and filtering, the signal is applied to one of the previous stages as a regulating voltage. In this type of circuit, a true amplification control is achieved by shifting the operating point of the input stage. That is, when a signal of large magnitude is encountered by this circuit, the regulating voltage increases and controls the operating point of the previous amplifier stage to decrease the amplification and therefore this circuit makes it possible to transmit signals of larger magnitude without appreciable distortion. The hearing aid prior art, however, teaches that a volume control with which the patient adjusts the amount of amplification to suit his individual requirements and his surrounding environmental requirements is usually found in an intermediate stage of the amplifier. That is, in a four stage amplifier volume control will most likely be found between the second and third stages. Because of the required voltage and current in order to accomplish the regulation, the signal can only be taken from the

output stage and this results in the volume control being contained within the regulation control loop. Therefore, an adjustment of the volume control inherently changes the operating point of the regulation circuit, that is, adjusting the volume control to lower the output volume also reduces the dynamic range of the control circuit until at a certain volume setting, no appreciable regulation occurs. In other words, the only useable regulation occurs at the highest amplification values of the amplifying circuit and it is very rarely that a person having a hearing loss will adjust the volume to this high level.

According to my invention, the disadvantage of the circuit just described can be eliminated by removing the volume control from the regulating control loop and exciting it beyond the regulating voltage control circuit. In other words, the adjustment of the volume control is substantially independent from the regulating or automatic gain control in the stage preceding it.

It is therefore a general object of the present invention to automatically regulate the amplification of a hearing aid circuit independent of the setting of the volume control.

It is still another object of the present invention to automatically regulate the gain of a hearing aid circuit so that the output signal remains within a predetermined dynamic range independent of the input signal.

It is still a further object of this invention to provide a hearing aid circuit in which the automatic gain control circuit and volume control circuit are substantially independent of each other.

It is yet another object of the present invention to provide an automatic gain control circuit driving a signal limiting device including a volume control in which the power output of the amplifier circuit is limited.

It is still a further object of the present invention to provide an automatic gain control circuit which operates substantially independent of a volume control circuit wherein the audio-frequency response may also be varied.

It is yet another object of the present invention to provide an automatic gain control circuit independent of the volume control circuit wherein the automatic gain control circuit compensates for a shift in the transistor operating point due to temperature variations.

These and other objects of the present invention will become more apparent from the accompanying drawings where similar reference characters designate corresponding parts and in which:

FIGURE 1 is a block diagram of my invention; and

FIGURE 2 is a schematic diagram of the essential part of the feedback loop.

Basically, in a hearing aid amplifier having four transistor stages, the volume control is placed between the third and fourth stages whereas the regulating voltage is obtained from the third stage ahead of the volume control to be applied to the automatic gain control. The automatic gain control circuit is created by using a special feedback amplifier which insures regulation over a wide span of amplitudes. This regulation is accomplished by rectifying the voltage obtained from the third stage of the hearing aid amplifier and amplifying the rectified voltage with a direct current amplifier. By converting the control voltage to direct current, a minimum amount of filtering is required which greatly aids in the placement of parts in a hearing aid because of the space limitation, and by resistance coupling of the feedback direct current signal, any shift in the operating point of a transistor amplifier stage due to temperature variation is automatically compensated. Generally stable operation is attempted by providing transistor amplifiers with well known temperature correction circuits to compensate for temperature influences since transistors are

affected by temperature in that the collector current rises and causes the working region or point of operation to shift. However, these circuits which are used to compensate for temperature variation generally adversely affect the amplification characteristics of the particular circuit. These shortcomings are overcome by my invention.

FIGURE 1 shows an amplifier circuit having four stages of amplification which are designated in block diagram form as V_1, V_2, V_3, and V_4. Microphone **10** is connected to transistor amplifier stage V_1 which in turn is connected to the input of amplifier stage V_2 by a lead **11**. Amplifier stage V_2 is connected to stage V_3 through another connecting lead **12** and the output of amplifier stage V_3 is connected to a rectifier circuit G through a connecting lead **13**. Rectifier G is connected to a feedback amplifier RV through a connecting lead **14** and the output of feedback amplifier RV is connected to the input of amplifier stage V_1 through a connecting lead **15**. It will be understood that amplifiers V_1, V_2, V_3, V_4, rectifier G, and feedback amplifier RV all have a common ground **16** to facilitate the completion of the signal circuits. A limiter designated by the reference D is connected to the output of amplifier stage V_3 through a connecting lead **17** and limiter D is connected in parallel with a volume control R. Volume control R is a potentiometer which has its wiper arm connected to a tone control circuit T which contains a pair of capacitors **18** and **19**, it being understood that the tone control may have the capacitors placed in parallel or series in order to modify the frequency characteristics of the incoming signals which is applied through a connecting lead **20** to amplifier stage V_4. The tone control is accomplished through a switch **21** which connects capacitor **18** or **19** into the circuit to accomplish the desired tonal qualities desired by the hearing aid wearer. Amplifier stage V_4 operates as an output amplifier and drives a hearing aid receiver **22** through a pair of connecting leads **23** and **24**.

Limiter D may take on several forms but for this particular application a pair of diodes **25** and **26** are connected in parallel with their poles opposing each other, that is they are connected in back-to-back parallel relationship.

In operation, a signal is received by amplifier stage V_1 and is amplified by stage V_2 and V_3 where the output signal from V_3 is applied to the rectifier G. Rectifier G not only rectifies the signal voltage but also smooths it to produce a direct current voltage of predetermined polarity and this voltage is applied to feedback amplifier RV. Feedback amplifier RV is a direct current type amplifier and the voltage output is applied to the input of amplifier stage V_1 so that any large transient voltage appearing at the output of amplifier stage V_3 is immediately smoothed and the direct current signal applied to the input of amplifier stage V_1 to reduce the overall amplification. Therefore, any sudden noise or change which is detected in the sound level by microphone **10** is immediately adjusted by the gain control features of feedback amplifier RV so that a signal which appears on connecting lead **17** is within a predetermined voltage range for the greater majority of sounds detected by microphone **10**. The signal which appears on connecting lead **17** is then applied to limiter D and if the voltage range just mentioned is not exceeded, limiter D has no affect and the signal is applied across volume control R which is in the form of a potentiometer. The signal which appears on the wiper arm of volume control R is applied to capacitor **18** or **19** depending upon the position of the switch arm of switch **21** and the signal is applied to the input of amplifier stage V_4. Amplifier stage V_4 may be any type of transistorized power output stage and the power output of amplifier V_4 is used to drive a hearing aid receiver such as **22**. From this description it may be seen that any adjustment made to volume control R or tone control T has substantially

no affect upon the signal which is applied to rectifier G and hence emerges as a control signal from feedback amplifier RV to amplifier stage V_1. Should the signal appearing across the resistive element of volume control R exceed a predetermined magnitude, diodes **25** and **26** will limit the voltage output and this occurs generally during a lag of the feedback signal where there has been a relatively low sound level impressed upon microphone **10**. Diodes **25** and **26** are usually selected so that it does pass all of the signals during normal operation and thus avoids the possible distortion.

FIGURE 2 shows the critical operation of the feedback circuit in schematic form in which microphone **10** is connected to ground **16** and to a capacitor **27**. The other side of capacitor **27** is connected to a resistance **28** which has its other terminal connected to ground **16**. The junction of capacitor **27** and resistor **28** is connected to the base of a transistor T_1. The emitter of transistor T_1 is connected to ground **16** and the collector is connected to a negative voltage supply through a load resistor **30**. It is of course understood that the negative voltage supply has the positive terminal connected to ground to complete the voltage circuit. A resistor **31** is also connected to the base of transistor T_1 and has its other terminal connected to the collector of a second transistor T_2. The collector of transistor T_2 is connected to the negative voltage supply through a load resistor **32** and the emitter of transistor T_2 is also connected to ground **16**. The base element of transistor T_2 is connected to rectifier G through a connecting lead **33** and it will be apparent that the input to rectifier G conducts a signal through a connecting lead **13** such as shown in FIGURE 1. FIGURE 2 shows in particular, the automatic feedback control circuit where resistors **28** and **31** form a voltage divider for the voltage which emerges from the collector of transistor T_2. Assuming that a strong signal appears on connecting lead **13**, voltage is rectified and filtered by a rectifier G and passed on to the base of transistor T_2 through connecting lead **33**. This voltage causes transistor T_2 to draw current through resistor **32** and the collector potential of T_2 shifts towards a positive value. This change of potential is applied to the base of transistor T_2 through resistor **31** and controls the operating point of transistor T_1 to lessen the gain of the transistor stage. Since the volume control is not contained in this circuit, the gain control is not affected by adjustment of the volume control and thus a true regulation is achieved. Referring briefly to FIGURE 1, once the patient sets the volume control R to a comfortable level, the feedback circuit as shown in FIGURE 2 keeps the signal level automatically constant, the signal level being practically independent of the input signal level. In a particular test conducted using the invention as set out in the schematic diagram, the output sound pressure changed approximately 6 db's while the input signal was varied between 50 and 110 db's (with reference to 2×10^{-4} microbars). No measurable difference could be detected of the output when still higher signal levels were introduced to the input.

The temperature stabilization of transistor T_1 can also be explained by referring to FIGURE 2. When the hearing aid circuit has voltage first applied to it, the tendency of the circuit to cause transistors T_1 and T_2 to have their temperatures increased and thereby cause both collector currents of transistors T_1 and T_2 to rise slowly. But while the current is rising in transistor T_2, the transistor T_1 has its operating point kept at a normal value because it obtains a correction voltage through the potential applied across resistor **31**. The amplifying properties of this stage are thus preserved even while being subjected to a rising temperature. The two additional amplifying stages V_2 and V_3 are stabilized in the well known manner of resistance coupling between the collector and base.

While the wiring diagram shown in FIGURE 2 couples the compensating voltage to the base of transistor T_1 it of course will be realized that the regulation voltage may also

be applied to the emitter of transistor T_1 instead of the base and achieve the same result.

From the teachings of my invention it will be seen that I have shown and described an automatic gain control circuit which is relatively isolated from the volume control while at the same time providing a high degree of stability against temperature changes in the input stages of the transistorized amplifier.

It will of course, be understood that various changes may be made in the form, details, arrangement and proportions of the parts without departing from the scope of my invention which consists of the matter shown and described herein and set forth in the appended claims.

I claim:

1. In a transistor hearing aid circuit, a circuit having automatic regulation of the output power comprising: an audio preamplifier having a plurality of stages including input and output terminals responsive to an electrical input signal to produce an output signal of larger magnitude than said input signal; a feedback control circuit including a rectifying circuit for converting alternating current signals of audio frequency to a direct current of predetermined polarity; first connecting means including said feedback control circuit for connecting said output terminal to said input terminal of said audio preamplifier to apply a controlling voltage to said input terminal which is representative of the magnitude of said preamplifier output signal; a power output amplifier having its input responsive to an electrical input signal to produce signals as its output for driving a load device; a volume control circuit having adjustable impedance elements to vary the signal output level thereof and having a pair of back-to-back diodes connected in parallel manner with said volume control circuit to form a limiting device to limit said input signals received by said power output amplifier to a predetermined magnitude during a lag of signals from said feedback control circuit; and second connecting means including said volume control circuit for connecting said output terminals of said preamplifier to the input of said power output amplifier so that said volume control circuit is substantially independent of said feedback control circuit.

2. In a transistor hearing aid circuit, a circuit having automatic regulation of the output power comprising: an audio preamplifier having a plurality of stages including input and output terminals responsive to an electrical input signal to produce an output signal of larger magnitude than said input signal; a feedback control circuit including a rectifying circuit for converting alternating current signals of audio frequency to a direct current of predetermined polarity; first connecting means including said feedback control circuit for connecting said output terminal to said input terminal of said audio preamplifier to apply a controlling voltage to said input terminal which is representative of the magnitude of said preamplifier output signal; a power output amplifier having its input responsive to an electrical input signal to produce signals at its output

for driving a load device; a volume control circuit having adjustable impedance elements to vary the signal output level thereof; and having means for varying the frequency response of said signal associated therewith; and second connecting means including said volume control circuit for connecting said output terminals of said preamplifier to the input of said power output amplifier so that said volume control circuit is substantially independent of said feedback control circuit.

3. In a transistor hearing aid circuit, a circuit having automatic regulation of the output power comprising: an audio preamplifier having a plurality of stages including input and output terminals responsive to an electrical input signal to produce an output signal of larger magnitude than said input signal; a feedback control circuit including a rectifying circuit for converting alternating current signals of audio frequency to a direct current of predetermined polarity; first connecting means including said feedback control circuit for connecting said output terminal to said input terminal of said audio preamplifier to apply a controlling voltage to said input terminal which is representative of the magnitude of said preamplifier output signal and including resistance coupling between said feedback control circuit and said preamplifier input terminals so that said controlling voltage to said input terminals compensates said preamplifier for transistor operating point shift due to temperature variations; a power output amplifier having its input responsive to an electrical input signal to produce signals at its output for driving a load device; a volume control circuit having adjustable impedance elements to vary the signal output level thereof; and second connecting means including said volume control circuit for connecting said output terminals of said preamplifier to the input of said power output amplifier so that said volume control circuit is substantially independent of said feedback control circuit.

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