United States Patent

[11] 3,571,514

[72] Inventor **Kenneth R. Wruk**
Joliet, Ill.
[21] Appl. No. **789,581**
[22] Filed **Jan. 7, 1969**
[45] Patented **Mar. 6, 1971**
[73] Assignee **Zenith Radio Corporation**
Chicago, Ill.

[54] **HEARING AID TONE CONTROL**
1 Claim, 5 Drawing Figs.

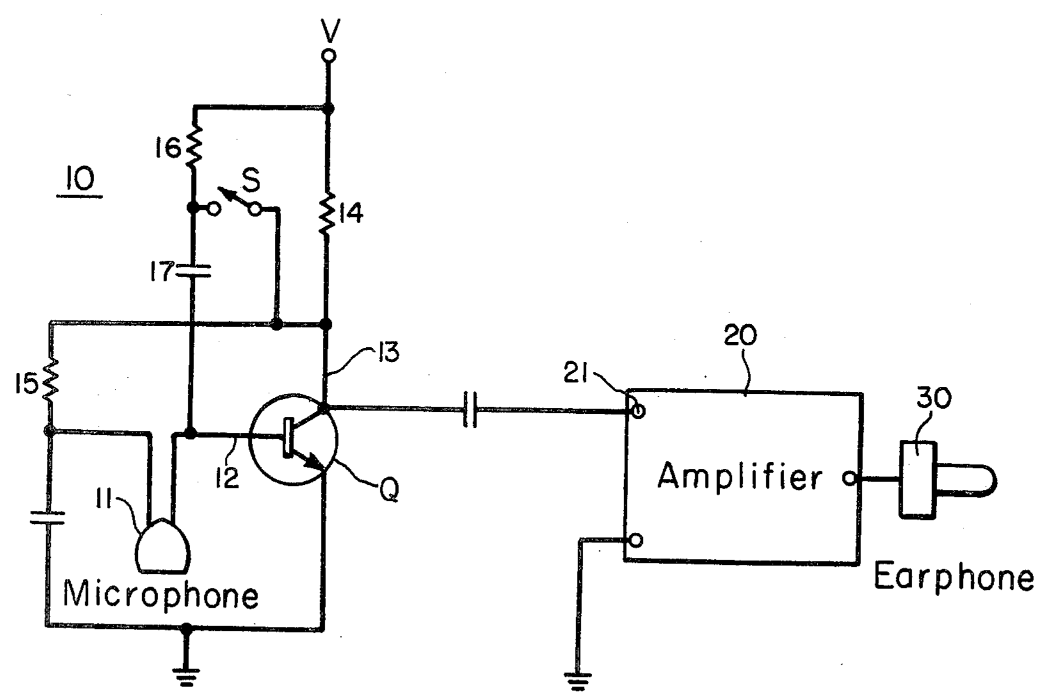
[52] **U.S. Cl.** **179/1,** 179/107
[51] **Int. Cl.** **H03g 5/12,** H04r 25/00
[50] **Field of Search** .... 179/1.2, 1 (A), 107, 1 (F); 330/96

[56] **References Cited**
UNITED STATES PATENTS

3,124,760	3/1964	Dijkstra	179/107
3,209,083	9/1965	Posen	179/107
3,491,203	1/1970	Shabad	179/107

Primary Examiner—William C. Cooper
Assistant Examiner—Douglas W. Olms
Attorney—John J. Pederson

ABSTRACT: A tone control circuit for a transistorized hearing aid amplifier comprising a transistor amplifier stage with an electromagnetic hearing aid microphone connected to its input. The output has a resistor connected thereto for establishing the operating point of the stage. A switch is provided for connecting a second resistor and a capacitor in parallel with the first resistor to change the operating point of the transistor in such a manner as to lower the input impedance of the transistor. The decrease in input impedance reduces the high frequency response of the microphone-transistor combination and thereby provides treble tone control action.



Patented March 16, 1971 3,571,514

2 Sheets-Sheet 1

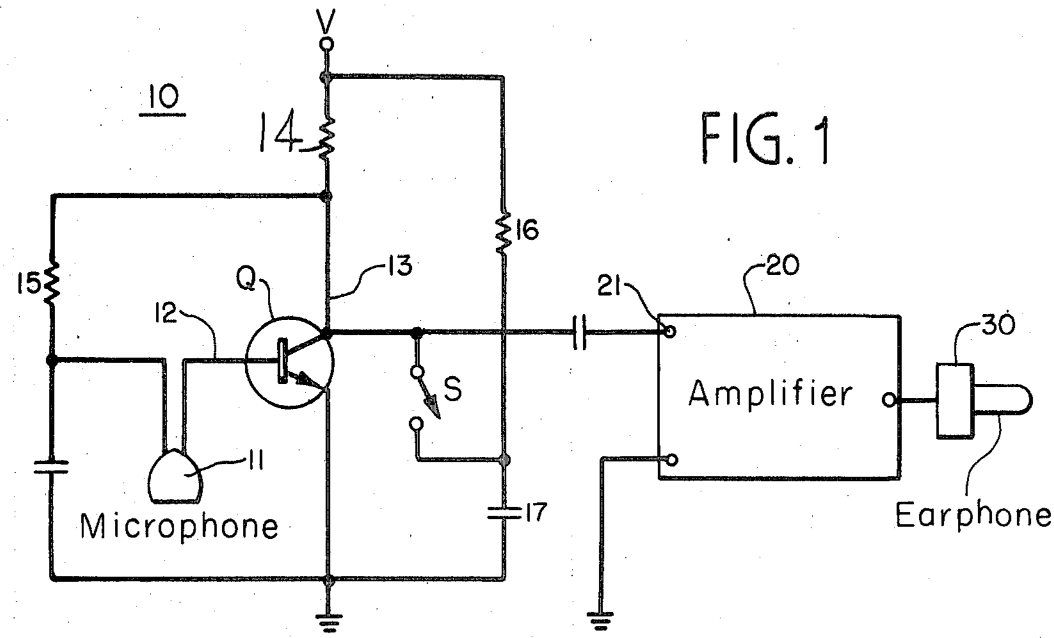


FIG. 1

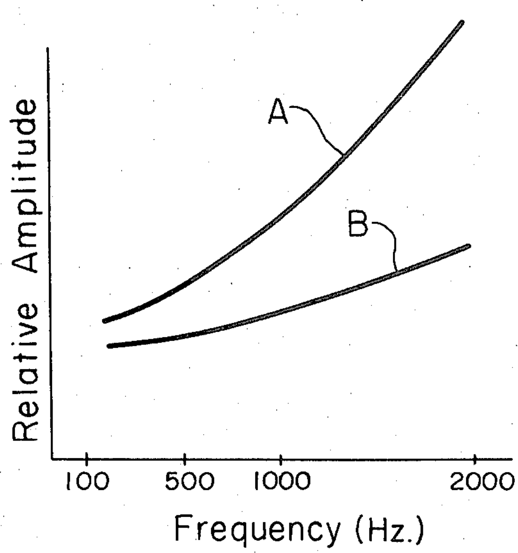


FIG. 2

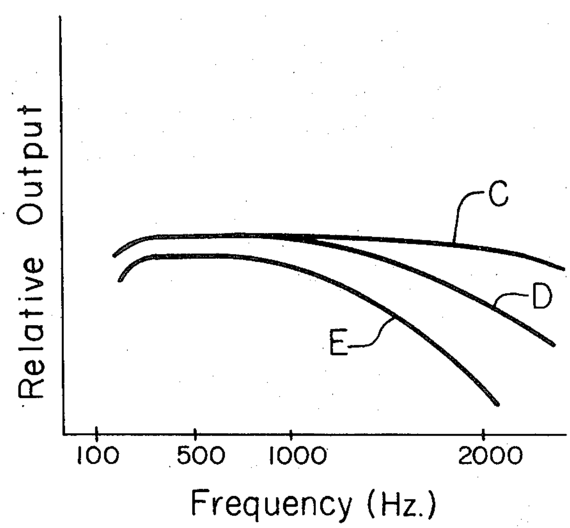


FIG. 3

Inventor
Kenneth R. Wruk
By John J. Pederson
Attorney

Patented March 16, 1971 3,571,514

2 Sheets-Sheet 2

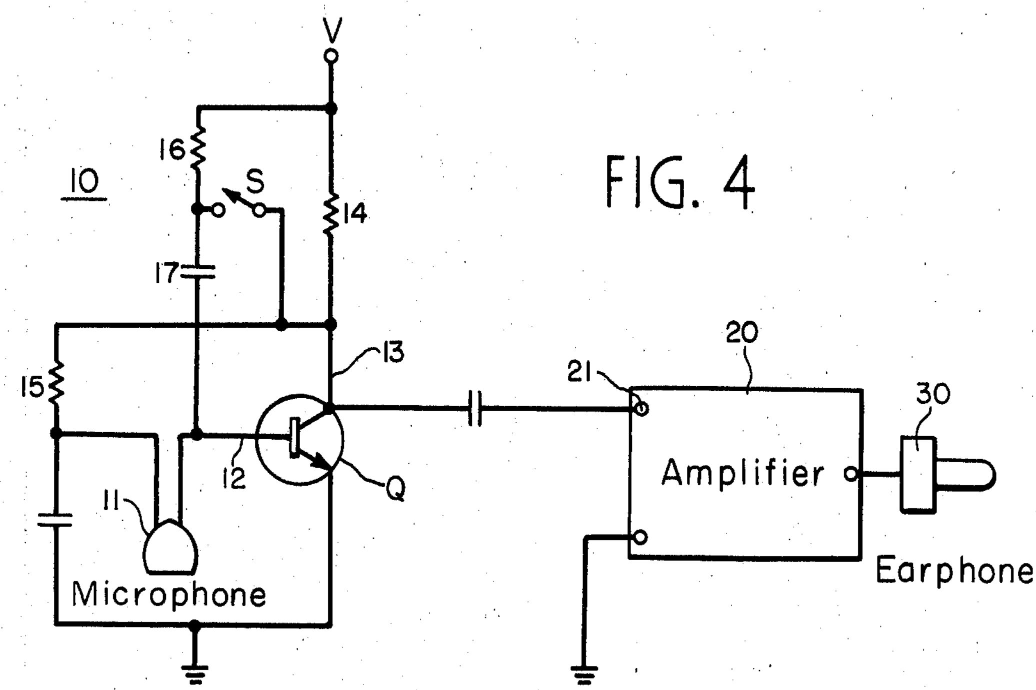
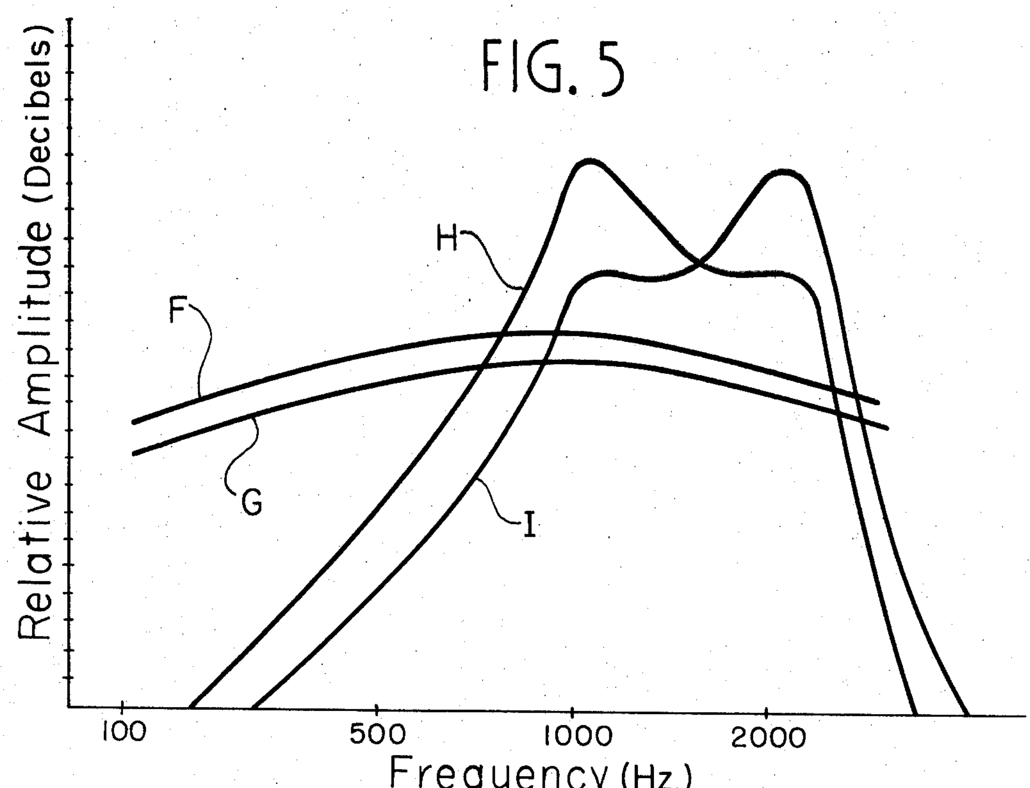


FIG. 4

FIG. 5



Inventor
Kenneth R. Wruk

By John J. Pederson
Attorney

HEARING AID TONE CONTROL

BACKGROUND OF THE INVENTION

This invention relates to tone control circuits, and more particularly to treble or high frequency tone control circuits suitable for use with transistorized hearing aid amplifiers.

Conventional audio amplifier tone control circuits typically employ a combination of reactive and resistive impedance elements introduced into the primary signal path to individually and selectively attenuate the treble and bass frequency components of the audio signal relative to one another. Certain of these impedance elements may be made variable by manual control in order that a desired frequency characteristic may be selected by an operator or user of the amplifier. Circuits of this type are generally of the signal divider type in which signal division is a manually controllable function of frequency. Generally speaking, such circuits are not required to meet stringent small size specifications.

Tone control circuits for hearing aids are widely used to permit the hearing aid user to adjust the frequency response of his aid to provide an intelligible and comfortable audio signal to his ear. A typical tone control application for a hearing aid amplifier provides selective treble frequency attenuation on the order of 9 to 11 decibels per octave. Conventional treble attenuation tone controls utilize capacitive impedance elements to provide this attenuation by shunting a portion of the treble frequency components of the audio signal from the primary signal path to ground. With a single capacitive impedance element, however, the maximum amount of attenuation possible is 6 decibels per octave. Thus, it is necessary to use more than one such component to obtain more than 6 decibels per octave attenuation. Such a multiple-capacitor circuit necessarily requires an increase in size for the amplifier. Moreover, despite the increasing public acceptance of hearing aids, compact size is still desirable with respect to convenience, directivity, and elimination of clothing noise. With this in mind, it is quite obviously desirable to minimize the size of the amplifier to enable a tone controlled hearing aid amplifier to be constructed with a maximum degree of miniaturization.

It is therefore an important object of the invention to provide a new and improved tone control circuit for a hearing aid amplifier.

It is a further object of the invention to provide a new and improved tone control circuit with a minimum number of components in order to obtain a maximum degree of miniaturization.

SUMMARY OF THE INVENTION

A tone-controlled hearing aid amplifier constructed in accordance with the invention comprises an amplifier device of the type comprising an input electrode and an output electrode, having a predetermined input-signal-to-output-signal amplifying characteristic, and an input impedance which varies with variations in the operating point on the characteristic. An electromechanical transducer, including a hearing aid microphone responsive to ambient audio sound waves and having a frequency response range which is narrow relative to that of the amplifier device, is coupled to the input electrode. Means including a load impedance coupled to the output electrode are provided for establishing a predetermined operating point for the device, whereby audio frequency signals developed by the transducer are amplified by the device and an amplified output signal is produced at the output electrode. An output transducer is coupled to the output electrode for converting the amplified output signal into intelligible audio information at a power level higher than that of the ambient waves, and means are provided for varying the operating point to vary the frequency response characteristic of the amplifier.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in the several FIGS. of which like reference numerals identify like elements, and in which:

FIG. 1 is a schematic diagram of a tone control circuit for a hearing aid amplifier embodying the principles of the present invention;

FIG. 2 is a graphical representation of the frequency response of the hearing aid tone control circuit shown in FIG. 1;

FIG. 3 is a graphical representation of the frequency response of the output signal of the hearing aid shown in FIG. 1;

FIG. 4 is a schematic diagram of another embodiment of the invention; and

FIG. 5 is a graphical representation of the frequency response of the embodiment shown in FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to FIG. 1, a new and improved tone control for a hearing aid amplifier constructed in accordance with the invention is shown which comprises the amplifier-tone control circuit **10**, including an NPN transistor Q, coupled to an appropriate amplifier circuit **20**, shown in block diagram form and which may be omitted without sacrificing satisfactory operation of the invention as explained below. An output transducer in the form of an earphone **30** couples the output signal of the hearing aid to the user's ear. Ambient audio sound waves are received by a miniature magnetic hearing aid microphone **11**, having a frequency response range which is narrow relative to that of transistor Q, wherein the sound wave signals are converted into electrical signals which are applied to the base **12** of transistor Q. Amplified electrical signals corresponding to the received audio sound waves are developed across a collector load resistor **14** and applied to input terminal **21** of amplifier **20**. Amplifier **20** provides an additional amount of amplification of the electrical signals, which is unnecessary if the amplifier-tone control circuit **10** provides the amount of amplification required to enable output transducer **30** to deliver intelligible audio information to the ear at a power level higher than that of the ambient sound waves and sufficient to enable the user to satisfactorily compensate his hearing deficiency.

In accordance with the invention, circuit **10** includes an amplifier device in the form of a transistor Q having an input electrode or base **12** and an output electrode or collector **13**. A load impedance in the from of collector load resistor **14** has the output signal developed across it and, in conjunction with bias resistor **15**, establishes the operating point of transistor Q on its input-signal-to-output-signal amplifying characteristic. The input impedance of transistor Q is directly dependent on the operating point of transistor Q. Consequently, effectively varying the collector load resistor **14** varies the input impedance of transistor Q. As the input impedance is reduced, the treble frequency response of the microphone-transistor input circuit is correspondingly changed. In the case of a magnetic microphone, the treble frequency response is reduced whereas in the case of a ceramic microphone, the opposite is true. In such manner it has been found that by utilizing a magnetic microphone, the treble frequency components of the output signal developed across load resistor **14** may be effectively attenuated at least four decibels per octave by simply varying the operating point of the transistor to reduce its input impedance.

The construction used in this embodiment for the variation of the operating point principle of the invention takes the form of a single-pole, single-throw (SPST) switch S adapted to connect a second resistor **16** in parallel with collector load resistor

14. When so connected, the load impedance of the amplifier device (transistor Q) is decreased, thus increasing the current through transistor Q and lowering its input impedance. It is quite possible, however, to obtain a similar result by other means, such as the utilization of a variable resistor for collector load resistor 14.

In addition, a maximum of 6 decibels of treble frequency attenuation is obtained by effectively coupling a capacitor 17 in parallel with collector load resistor 14 as shown in FIG. 1. Capacitor 17 is therefore simultaneously coupled with resistor 16 to the collector 13 by switch S and shunts a portion of the treble frequency components from the primary signal path to ground. Alternatively, capacitor 15 may be connected directly in parallel with resistor 14, although it has been found that the possibility of inducing unwanted oscillations in the output signal is increased by such a configuration.

The 6 decibels per octave treble frequency attenuation contributed by connecting capacitor 17 into the circuit augments the 4 decibels supplied by shifting the transistor's operating point and thereby provides a total treble frequency attenuation of 10 decibels per octave. Moreover, only one capacitor and one resistor, controlled by a single small SPST switch, are required to accomplish this result and the maximum miniaturization objective of the invention is achieved.

FIG. 2 is a graphical representation illustrating the frequency response characteristic, observed at the junction of the base 12 of transistor Q and the microphone 11, for a magnetic hearing aid amplifier. Curve A represents the frequency response when the transistor has a relatively large input impedance, for example 100,000 ohms. Curve B on the other hand, illustrates the frequency response when the input impedance of transistor Q is relatively low, for example 10,000 ohms. Thus it may be observed that, for a hearing aid amplifier having a relatively uniform output signal level (i.e., a "flat" frequency response) when its microphone operates into a relatively high impedance, an effective treble attenuation tone control may be established by changing the operating point of the input transistor to reduce the input impedance of the transistor and thereby reduce the treble frequency response of the hearing aid amplifier. When this result is augmented by a capacitor shunt-type tone control as described above, a total amount of tone control action greater than that of conventional circuits using similar components is obtained.

The difference in performance between the invention and conventional circuits is graphically represented in FIG. 3. Curve C represents a relatively uniform output signal level or "flat" frequency response for a typical hearing aid amplifier. Connecting capacitor 17 alone into the circuit 10, in accordance with conventional circuits and as described above, yields a maximum treble frequency attenuation of 6 decibels per octave as illustrated by curve D. In accordance with the invention, however, additional treble frequency attenuation of at least 4 decibels per octave is obtained by the invention as described above to provide a total of at least 10 decibels per octave as illustrated by curve E.

The following is a list of component values for the circuit of FIG. 1 which have been found to provide satisfactory operation in accordance with the invention. It is understood that these are given solely by way of example and that other values may be substituted therefore without departing from the principles of the present invention.

Resistor 14—47,000 ohms
Resistor 15—100,000 ohms
Resistor 16—8,200 ohms
Capacitor 17—0.1 microfarads
Transistor Q—Fairchild 2N4249

With reference to FIG. 4, a circuit similar to that of FIG. 1 is shown which, in accordance with the invention, provides an even greater amount of tone control action than that of the embodiment shown in FIG. 1. By placing resistor 16 and capacitor 17 between the power supply (indicated by V) and the base 12 of transistor Q, as shown the advantageous results of the invention are enhanced. The value of capacitor 17 for this embodiment, is reduced to a much smaller value than that used in FIG. 1; for example, 0.002 microfarads. When the switch S is closed, resistor 16, similar to the operation of the embodiment shown in FIG. 1, shifts the operating point of transistor Q to bring about the impedance change and the corresponding frequency response change of the circuit.

The smaller value of capacitor 17, connected to base 12 in this embodiment, however, provides sufficient feedback to reduce the treble frequency input impedance a significant amount and thereby cooperates with the magnetic microphone 11 to effect a substantial amount of treble frequency attenuation. This is not the conventional type of capacitive feedback circuit used to attenuate treble frequencies, which is limited to a maximum of 6 decibels per octave, but rather a unique combination of a relatively small value capacitor operating in conjunction with a magnetic microphone in such a manner so as to produce a total amount of treble frequency attenuation approximately 14 decibels per octave.

To aid in the understanding of the operation of this embodiment, the following example is provided. It has been found that the input impedance of transistor Q in this circuit with the component values listed above and switch S open is approximately 47,000 ohms both at bass frequencies (e.g. 500 Hz.) and at treble frequencies (2,500 Hz.). Closing switch S lowers this input impedance to approximately 10,000 ohms at bass frequencies and approximately 1,800 ohms at treble frequencies. By using a magnetic microphone in this situation, 14 decibels per octave treble frequency attenuation is achieved without appreciably attenuating bass frequencies. This remarkable result would not be achieved if microphone 11 were replaced by a different device, such as a ceramic microphone, which does not have the magnetic microphone's special frequency impedance characteristic as illustrated in FIG. 2. It is also understood that the above values are merely illustrative examples and that other values may be substituted therefor without departing from the principles of the invention.

Referring to FIG. 5, the electrical frequency response of the circuit 10 is graphically represented by curve G. Such a response is obtained by replacing microphone 11 with a linear electrical generator. Curve F shows the change in the electrical frequency response of circuit 10 when the switch S is closed. Thus it can be seen that, for a linear generator providing the source of signals for circuit 10, the closing of switch S does not change the frequency response of the system, but slightly alters the overall gain of the circuit.

Curves H and I illustrate the acoustic frequency response of the circuit 10 for switch S open and closed, respectively. The acoustic frequency response is that obtained when a magnetic hearing aid microphone 11 is the signal source for circuit 10, as shown in FIG. 4. It is quite apparent from comparing the two curves that, relative to the gain at 1,000 Hz., the gain at 2,000 Hz. (one octave higher) is changed approximately 14 decibels.

Thus a new and improved tone control circuit for a hearing aid amplifier has been shown and described which provides effective tone control with a minimum number of parts. More specifically, at least 10 decibels per octave of treble frequency attenuation is provided while utilizing only a single capacitive impedance element in contrast with the maximum of 6 decibels per octave attenuation provided by conventional circuits using a single such component. The additional resistor utilized by the invention does not handicap its miniature size feature inasmuch as integrated circuit (IC) technology has provided miniature transistor-resistor circuitry particularly adaptable to hearing aid amplifiers. Integrated circuit capacitors, on the other hand, are still many times larger than their transistor-resistor IC counterparts. Thus, a substantial step forward towards maximum miniaturization for a hearing aid tone control circuit is accomplished by the invention.

While a particular embodiment of the invention has been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. A tone-controlled hearing aid amplifier comprising:

an amplifier device of the type comprising an input electrode and an output electrode and having a predetermined input-signal-to-output-signal amplifying characteristic and having an input impedance which varies with variations in the operating point on said characteristic;

an electromechanical transducer, including a magnetic hearing aid microphone responsive to ambient audio sound waves and having a frequency response range which is narrow relative to that of said amplifier device, coupled to said input electrode;

means including a load impedance coupled to said output electrode for establishing a predetermined operating point for said device, whereby audio frequency signals developed by said transducer are amplified by said device and an amplified output signal is produced at said output electrode;

an output transducer coupled to said output electrode for converting said amplified output signal into intelligible audio information at a power level higher than that of said ambient waves; and

tone control means including a resistor, a capacitor, and a switch operable to simultaneously connect said resistor in parallel with said load impedance and said capacitor from said output electrode to said input electrode, thereby decreasing said input impedance and providing treble frequency attenuation of greater than 6 decibels per octave with a single reactive component.