FIG. 1

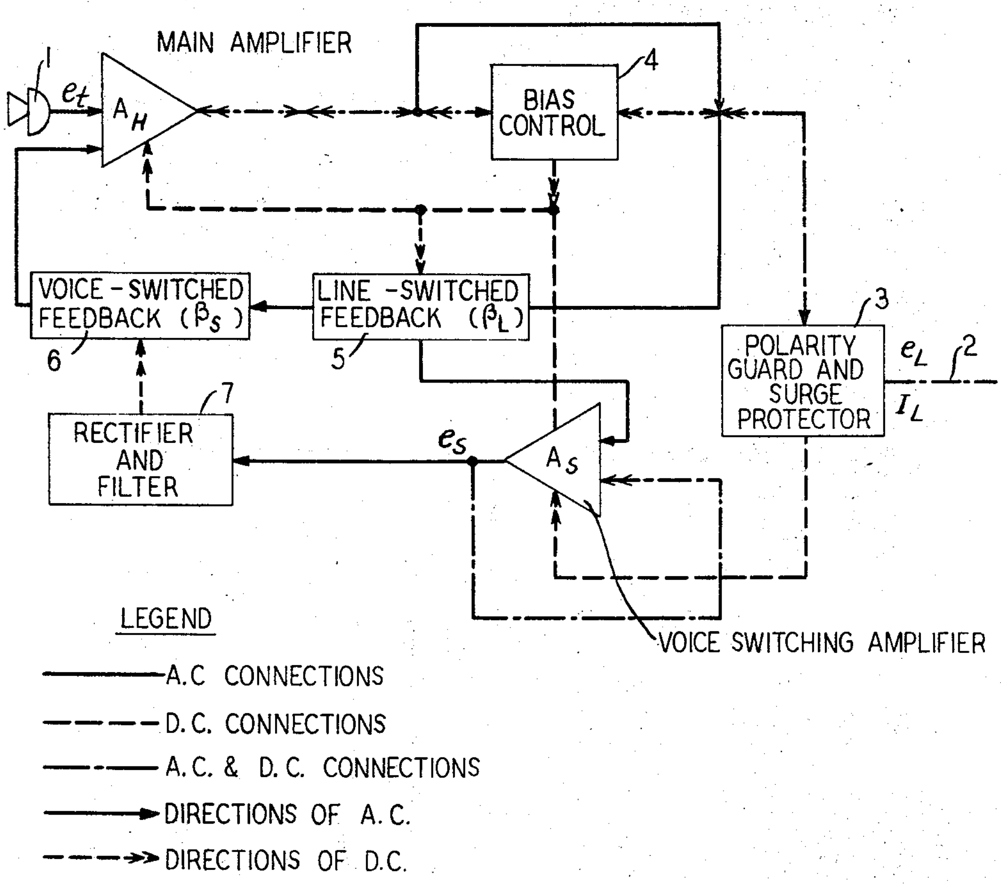
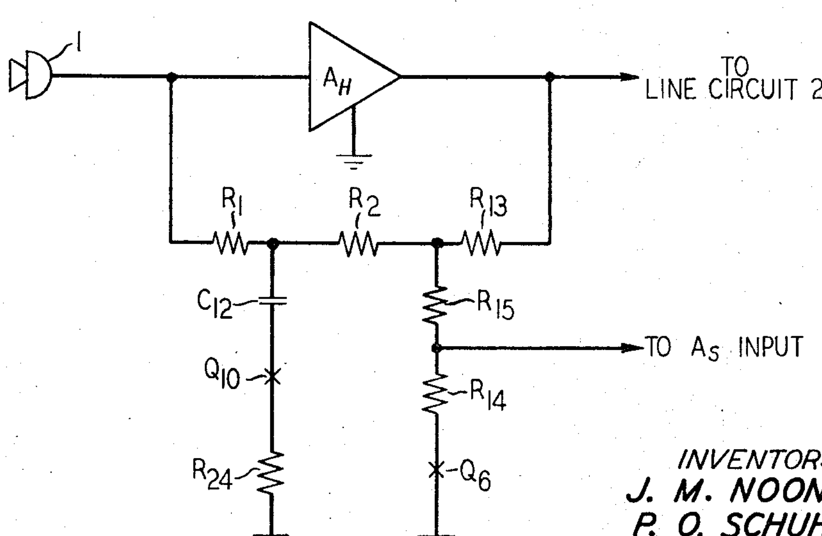


FIG. 3



INVENTORS
J. M. NOONAN
P. O. SCHUH
BY Charles E. Graves
ATTORNEY

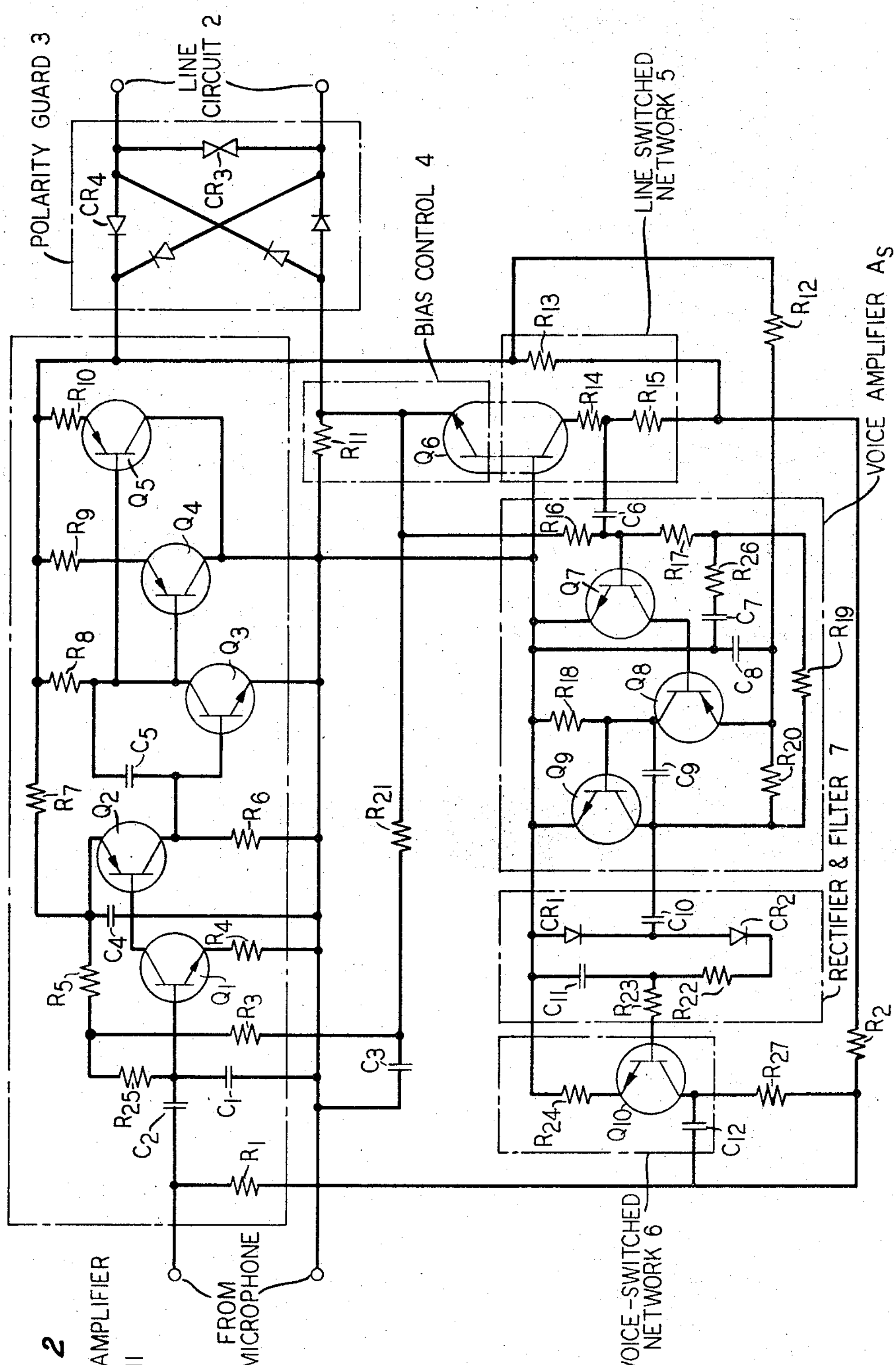

POLARITY GUARD 3
LINE CIRCUIT 2
CR4
CR3
BIAS CONTROL 4
LINE SWITCHED NETWORK 5
VOICE AMPLIFIER As
RECTIFIER & FILTER 7
VOICE-SWITCHED NETWORK 6
FROM MICROPHONE
MAIN AMPLIFIER A11
Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19 R20 R21 R22 R23 R24 R25 R26 R27
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12
CR1 CR2

FIG. 2

United States Patent Office

3,536,838

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AMPLIFIER WITH VOICE- AND LINE-SWITCHED GAIN CONTROLS IN NEGATIVE FEEDBACK PATH

John M. Noonan and Peter O. Schuh, Indianapolis, Ind., assignors to Bell Telephone Laboratories, Incorporated, Murray Hill and Berkeley Heights, N.J., a corporation of New York

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Int. Cl. H03g 3/20
U.S. Cl. 179—1 8 Claims

ABSTRACT OF THE DISCLOSURE

This is an electronic amplifier intended primarily for head telephone sets, that incorporates an automatic bias adjustment and a negative feedback loop with two independent controls. The bias adjustment allows the amplifier to operate linearly over a wide range of DC currents in the line to which an amplifier is connected. The negative feedback loop consists of a voice-switched gain responsive to normal speech level but not normal background noise, and also a line-switched gain which reduces amplification in response to line current level. The voiced switching threshold is held at a constant level regardless of the line current and the amplifier's automatic bias adjustment.

FIELD OF THE INVENTION

This invention is concerned with electronic amplifiers and, in particular, involves a universal amplifier for use in substantially all head telephone sets which employ microphones other than the carbon transmitter.

BACKGROUND OF THE INVENTION

Head telephone sets are used in the telephone plant principally by central office operators and PBX attendants. Their work situations have in common an appreciable level of background noise which in the interest of clear transmission must be suppressed. The carbon transmitter used in the past is inherently unresponsive to most background noise. Where other type microphones are used to lighten the set's weight, background noise must be electronically attenuated. Frequently also, amplification of the speech signals received by the microphone is also necessary.

In the suppression of background noise, it is convenient to use the anticipated operator speech levels to automatically control the gain of the amplifier. One such voice-switching expedient is taught in Pat. 3,368,158 of W. J. Brown, assigned to applicants' assignee where a headset amplifier discriminates on an instantaneous amplitude basis. While attractive for its simplicity, the device in some situations introduces a degree of distortion. Needed is an amplifier that discriminates on an average amplitude basis to avoid the problem of distortion, and yet which retains the virtue of simplicity.

Realizing this type of voice-switched gain in a particular amplifier, however, is complicated by the widely differing circuits into which the amplifiers must operate. For example, current available to the amplifier varies from about 3 milliamperes in some locations to over 130 milliamperes in others. If the headset microphone amplifier is to be usable universally regardless of the available current, some characteristic of the circuit which the amplifier feeds must be automatically sensed; and in response thereto, the gain of the amplifier must be adjusted to ensure linear operation within a current range appropriate to the circuit conditions. And yet, under all conditions, the voice-switched gain threshold must be held constant.

Accordingly, one broad object of the invention is to realize in a single amplifier the functional capabilities of voice-switched gain control, and automatic gain adjustment depending upon the specific value of a working circuit parameter.

A specific object of this invention is to achieve linear operation of a telephone transmitter amplifier while maintaining a constant threshold of voice-switched gain control, under widely varying line circuit DC current levels.

Another object of the invention is to electrically discriminate against operator position background noise without introducing distortion into normal voice amplification.

SUMMARY OF THE INVENTION

These and other objects are achieved pursuant to the invention by combining in an amplifier a negative feedback loop, dually controlled by a voice-switched feedback network (β_S) and by an independent line-switched feedback network (β_L). As is well known in the art the symbol β is used to denote the feedback factor; refer to Electronic Engineering, Ally and Atwood; Wiley, 2nd ed., 1966, p. 438. Associated with the loop is a first network for adjusting the amplifier gain in accordance with the available current in the line circuit into which the amplifier works and a second network which causes the gain of the voice-switch amplifier to vary inversely with the gain of the headset amplifier thus keeping the voice-switching threshold at a preselected constant level.

The line-switched β control is derived from a circuit which detects the level of line current. With values of line current greater than a set amount, part of the main amplifier feedback is shunted out, causing the amplifier gain to increase. Control of the voice-switched β is achieved by feeding a portion of the main amplifier output into a second amplifier, rectifying and filtering it, and then causing it to operate on another portion of the main amplifier feedback. With but normal background noise, this circuit does not alter the primary feedback which holds the gain low enough to attenuate the noise. But with inputs above a certain value, taken to be the level of normal close-up speech, the voice-switched β is reduced to allow normal gain for anticipated speech levels.

Pursuant to one facet of this invention, regardless of the current in the line circuit in which the amplifier is used, the switching threshold of the voice-switched β is maintained at a predetermined level corresponding, for example, to a pressure of about 75 dbt at the tip of a headset speech tube. Significantly, the voice-switching threshold is kept independent of the amplifier gain adjust.

In one specific inventive embodiment, the voice-switched gain comes into play only after the passage of a predetermined span of time. In this fashion, the thumping sound resulting from too fast a turn-on as well as the speech clipping resulting from too slow a turn-on are avoided. Further, the voice-switched gain is held between speech syllables to prevent any speech break-up.

Accordingly, one feature of the invention is an amplifier with a circuit that senses the current available for its powering, and adjusts the amplifier bias to increase amplifier voltage as a function of increasing load current.

Another feature of the invention involves separate voice-switched gain and line-switched gain controls operating in a cascaded negative feedback circuit to adjust amplifier gain automatically in accordance both with the current available in the line circuit and the input signal level.

The invention, its further objects, features and advantages will be fully apprehended from a reading of the following detailed description of an illustrative embodiment in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWING

FIG. 1 is a functional circuit diagram in block form depicting the overall operation of the invention;

FIG. 2 is a circuit schematic diagram of one circuit which practices the invention; and

FIG. 3 is a circuit schematic diagram depicting the feedback control paths.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

Overall structure

The invention is described hereinafter in an embodiment involving a telephone operator's headset. Numerous other environments will readily come to mind, however; in which the invention can find use.

The block diagram of FIG. 1 represents an overall amplifier system embodying the present invention. The legend associated with FIG. 1 distinguishes the connections between the various components as being solely AC, solely DC or both AC and DC; and also distinguishes the direction of AC and the direction of DC. The symbols using in connection with FIG. 1 and in the specification to follow have the following meanings:

e_t=AC voltage from transmitter unit **1**
e_L=AC voltage delivered to line **2**
e_s=AC voltage delivered to rectifier and filter **5**
I_L=DC current available at line **2**
A_H=Headset amplifier
A_S=Voice-switching amplifier
β_L=Line-switched feedback
β_S=Voice-switched feedback

The amplifier system consists of headset microphone **1** connected to a headset amplifier A_H. The output of amplifier A_H is applied to a telephone line designated **2** through a polarity guard and surge protector **3**. DC power is available at line **2**, but in widely varying amounts from case to case.

Amplifier A_H receives DC bias from a bias control **4** which monitors the line current and adjusts the bias accordingly. The AC output of amplifier A_H by-passes bias control **4** and is applied to line **2** through polarity guard **3**.

As shown in FIGS. 1, 2, and 3, a portion of this output is applied to a cascaded negative feedback loop consist- of a line-switched network **5** and input-switched network **6**, which in the present invention is voice-switched. Network **5** derives a DC control input from the bias control loop linking bias control **4** with amplifier A_H. Network **5** serves to reduce the feedback of amplifier A_H with line circuit currents above a set level, thus increasing the gain.

A portion of the output signal e_L is applied to amplifier A_S thru network **5**. Amplifier A_S amplifies this signal to a level sufficient for rectification in the rectifier and filter circuit **7**. The rectifier signal is applied then to network **6** where it serves to reduce the negative feedback when the speech input to microphone **1** is over a certain value. Importantly, network **5** is included as part of the switching signal path in order to keep the voice-switching threshold independent of the gain e_L/e_t.

DETAILED CIRCUIT STRUCTURE

Headset amplifier

A specific circuit configuration which practices the invention is shown in FIG. 2. The headset amplifier A_H is a four-stage, direct coupled amplifier consisting of transistors Q_1, Q_2, Q_3, Q_4, and Q_5. Power is derived from the line current **2** to which amplifier A_H is connected. The amplifier A_H must handle up to 130 milliamperes of current, most of which must pass through the output stages Q_4 and Q_5. The latter hence are connected in parallel to dissipate this high power when it occurs; and emitter resistors R_9 and R_{10} of transistors Q_4 and Q_5 are of low but sufficient value to provide equal current division between the two transistors. The AC output signal e_L is decoupled from transistors Q_1 and Q_2 by a loop consisting of resistor R_7 and capacitor C_4. Capacitor C_1 provides high frequency attenuation to achieve the proper response characteristic for voice frequency inputs.

Capacitor C_3 and resistor R_{21}, acts as a decoupling circuit to prevent the output signal developed across R_{11} from being fed back to the base of Q_1. Resistors R_3, R_4, R_5, R_{21}, and R_{25} are used to bias amplifier A_H with resistor R_{25} being employed to raise the input impedance of the amplifier. Resistor R_6 acts as a load resistor for transistor Q_2 while capacitor C_2 acts as a coupling capacitor to isolate the DC resistance of the microphone **1** from the amplifier A_H. Capacitor C_5 provides additional high frequency attenuation.

Bias adjust

For amplifier A_H to operate linearly on currents ranging from 3 to 130 milliamperes, the bias to transistors Q_1–Q_5 is, pursuant to the invention, adjusted according to the amount of current available. The bias control **4** consists essentially of resistor R_{11} and the emitter-to-base resistance of transistor Q_6 which functions in the line-switched network **5** in a manner to be described. Resistor R_{11} is connected in series with the base bias resistors R_3, and R_{21}, of amplifier A_H and the base bias resistor R_{16} of switch amplifier A_S. The voltage drop occurs across resistor R_{11} varies with the DC line current I_L. Accordingly, the voltage drop between circuit common and the base of transistors Q_1 and Q_7 is increased, thus causing these transistors to conduct more current. Similarly, if I_L is a lower value the base voltage of transistors Q_1 and Q_7 is reduced resulting in less collector current.

Line-switched gain

The operator headset of the present embodiment might be used in a PBX circuit which already includes an amplifier, thus negating the need for some of the gain provided by amplifier A_H. The feedback network **5** shown in FIGS. 1 and 2 provides the line-switched gain, β_L to enable the over amplifier system of the present invention to adapt to this type circuit. To this end, network **5** detects I_L, the DC current available at line circuit **2**.

The specific control of β_L is derived through resistor R_{13} and the shunt path consisting of resistor R_{14}, R_{15} and the collector-to-emitter resistance of transistor Q_6. The voltage drop across resistor R_{11}, which as earlier described forms part of the bias adjust feature of the invention, is also used to control the on-off state of transistor Q_6.

When the amplifier A_H feeds into a PBX circuit, I_L will be less than, say, 30 milliamperes. There will be an insufficient voltage drop across resistor R_{11} to cause it to turn on transistor Q_6. Therefore, the overall feedback loop for amplifier A_H includes resistors R_{13}, R_2 and R_1. When I_L is greater than, say, 40 milliamperes as occurs if the line circuit **2** is an operator's cord circuit, the emitter-base junction of transistor Q_6 becomes saturated and the collector resistance approaches zero. Therefore, the feedback signal is shunted by the path consisting of resistors R_{14} and R_{15} and the internal resistance of transistor Q_6. This shunting causes the gain of amplifier A_H to be increased by a predetermined amount.

Voice-switched gain

The feedback network **6** shown in FIGS. 1 and 2 provides the voice-switched gain, β_S for amplifier A_H. Network **6** consists of a first path comprising series resistors R_1 and R_2, which is shunted when required by the path comprising capacitor C_{12}, resistor R_{24} and the collector-to emitter resistance of transistor Q_{10}.

The mode of transistor Q_{10} is controlled by the level of a DC voltage developed in the rectifier-filter circuit consisting of capacitors C_{10}, C_{11}, diodes CR_1, CR_2, and resistors R_{22}, R_{23}. The signal applied to this circuit is obtained from voice-switching amplifier A_S which, it will be recalled, derives its input as a portion of the output of amplifier A_H. In FIG. 2, amplifier A_S is shown as a three-stage direct-coupled amplifier consisting of transistors Q_7, Q_8, Q_9 and their associated resistors R_{16}, R_{17}, R_{18}, R_{19}, R_{20}, and R_{26}, and capacitors C_6, C_7, and C_9. Power for amplifier A_S is derived from the line circuit **2** through a resistor R_{12}. Capacitor C_8 decouples the output voltage e_L from amplifier A_S. A conventional AC and DC feedback circuit from the collector of transistor Q_9 to the base of Q_7 through resistors R_{17} and R_{19} stabilizes the DC bias and AC gain of amplifier A_S. The gain of amplifier A_S is adjusted by varying the value of resistor R_{26} which limits the decoupling obtained from capacitor C_7. Resistor R_{26} could, of course advantageously be a potentiometer.

Operation

The basic system requirements for the operator's headset through which the invention is being illustrated are principally two-fold. The headset amplifier A_H must operate linearly into either an unamplified operator's cord circuit or a PBX circuit which utilizes a telephone set network and its own amplifier. Then, the amplifier must attenuate background noise below a certain level.

The presence of the amplifier in a PBX circuit, however, reduces the gain required from amplifier A_H. As noted, this reduction is achieved by varying the feedback β_L of network **5** which detects the line circuit current.

The voice-switching of the gain of amplifier A_H is achieved by coupling a portion of the output signal e_L into amplifier A_S, rectifying and filtering the output and feeding to network **6**. If the resulting DC voltage is sufficient to turn on transistor Q_{10}, the feedback loop for amplifier A_H is shunted by a path consisting of capacitor C_{12}, transistor Q_{10} and resistor R_{24}. The negative feedback thus is reduced, and the gain e_L/e_t is increased. Advantageously, resistors R_2 and R_{24} are chosen in the instant embodiment to produce a gain increase for e_L/e_t of about 10 db.

Voice-switching threshold

The voice-switched gain provides normal gain for anticipated operator speech levels and otherwise attenuates background noise and adjacent operator pick-up. Advantageously, the voice-switching threshold is chosen to correspond to about 75 dbt at the speech tube tip. This characteristic must obtain regardless of the circuit into which the amplifier operates. This in turn requires that the voice-switching threshold be kept completely independent of the bias adjust feature earlier described, which effects the gain control of amplifier A_H.

Pursuant to the invention, this requirement is achieved by including the feedback network **7** as part of the switching signal path. Specifically, as seen in detail in FIG. 2, amplifier A_S is connected to network **7** through capacitor C_6. It thus is seen that, as β_L changes, the gains e_L/e_t and e_s/e_L vary inversely with respect to each other.

This assures that the switching gain e_s/e_t which fixes the voice-switching threshold, is constant and independent of β_L.

Too fast or too slow a turn-on of transistor Q_{10} which would cause thumping in the output of amplifier A_H, is avoided by proper choice of charge time on C_{11} which is controlled by R_{22}. Also, to ensure that Q_{10} remains on between speech syllables, the discharge time of C_{11} advantageously is 250 milliseconds.

The flexibility of the present amplifying circuitry extends beyond its ability to operate into circuits with widely varying current supplies. It is also readily possible to adjust the critical gains and switching thresholds.

For example, by varying the value of resistor R_{26} the gain of amplifier A_S is adjusted which would turn on transistor Q_{10} at a different speech threshold. Also, the negative feedback controlling the voice-switched gain is determined by the ratio R_2/R_{24}, provided the resistance of resistor R_{24} is substantially larger than the collector resistance of transistor Q_{10}. Furthermore, the line-switching threshold is fixed by the choice of transistor Q_6 and the value of resistor R_{11}.

The negative feedback controlling the amount of line-switched gain is determined by selecting appropriate values for resistors R_{13}, R_{14} and R_{15}. Additionally, as is apparent from FIG. 3, the values of resistors R_1 and R_2 in the feedback path of amplifier A_H determine the maximum feedback level. Those resistive components whose chosen values fix the aforementioned operating points can be provided as potentiometers or step resistances, for example, if desired.

Component values and data with which to achieve the desired operation of the above-described circuit when applied to an operator's headset microphone amplifier are listed below, where resistances are in ohms and capacitances are in microfarads.

R_1=75K	R_{21}=10K
R_2=75K	R_{22}=10K
R_3=10K	R_{23}=39K
R_4=2.7K	R_{24}=3K
R_5=39K	R_{25}=10K
R_6=2.7K	R_{26}=51
R_7=1.0K	R_{27}=120K
R_8=3.0K	C_1=.01
R_9=6.2	C_2=1.0
R_{10}=6.2	C_3=1.0
R_{11}=18	C_4=22.0
R_{12}=240	C_5=.001
R_{13}=2K	C_6=.33
R_{14}=240	C_7=22.0
R_{15}=750	C_8=22.0
R_{16}=33K	C_9=.003
R_{17}=6.8K	C_{10}=1.0
R_{18}=2.7K	C_{11}=1.0
R_{19}=10K	C_{12}=1.0
R_{20}=2K	

CR_1, CR_2=silicon rectifier diode
CR_3=silicon symmetrical surge protecting diode
CR_4=germanium full wave bridge
Q_1=low noise NPN silicon transistor
Q_2, Q_4, Q_5, Q_8=PNP silicon transistor
Q_3, Q_6, Q_7, Q_9, Q_{10}=NPN silicon transistor

It is to be understood that the embodiments described herein are merely illustrative of the principles of the invention. Various modifications may be made thereto by persons skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An amplification circuit for a telephone set comprising:

an amplifier with a negative feedback loop, input connectors from a microphone, and output connectors to a line circuit;

means sensing the line current level for adjusting the amplifier bias level to maintain linearity;

means responsive to recorded speech signals above a predetermined level for applying a first shunt path to a portion of said feedback loop; and

means responsive to sensing of line current above a set level for applying a second shunt path to a portion of said feedback loop.

2. An amplifier circuit comprising:

a main amplifier having an input and an output;

a line circuit connecting to said main amplifier for receiving said output, said line circuit containing a DC current of varying level for powering said main amplifier;

a negative feedback loop connected across said main amplifier and comprising 1st and 2nd serially connected networks;

said first network having a line current-switched feedback factor and said second network having an input-switched feedback factor;

means connecting said first network to said line circuit and responsive to DC current levels therein above a specified level for effecting a control of said line current-switched feedback factor; and

means connecting said second network to said main amplifier output and responsive to said output above a specified level for effecting a control of said input-switched feedback factor.

3. A voice frequency amplifier circuit comprising:

a main amplifier having a voice frequency input and output;

a line circuit containing DC current of varying level connected to said main amplifier for powering same and for receiving said output;

a negative feedback loop connected across said main amplifier and comprising 1st and 2nd serially connected networks, said first network comprising a line current-switched feedback factor and said second network comprising a voice input level-switched feedback factor;

means connecting said first network to said line circuit and responsive to DC current levels therein above a specified level for effecting a control of said line current-switched feedback factor;

means connecting said second network to said main amplifier output and responsive to said output above a specified level for effecting a control of said input-switched feedback factor; and

means connected between said line circuit and said main amplifier responsive to DC line current level for controlling the gain of said main amplifier to keep the operating point thereof in the linear region.

4. An amplifier circuit in accordance with claim 3, wherein said first network comprises a first resistive element in series relation in said negative feedback loop and a shunting path comprising a first transistor switch, said path reducing the net feedback factor of said first network on closure of said first switch.

5. An amplifier circuit in accordance with claim 4, wherein said main amplifier gain control means comprises a resistive element connected in series relation with the biasing elements of said main amplifier, and wherein said first transistor switch is connected across said resistive element, current levels in said line circuit effecting the voltage drop across said resistive element, thereby to adjust said main amplifier gain and to control the mode of said first transistor switch.

6. An amplifier circuit in accordance with claim 5, wherein said second network connecting means comprises a second amplifier, means for coupling a portion of said main amplifier output signal thereinto for amplification sufficient to permit later rectification, and rectifying means; and wherein said second network comprises a first resistive element in series relation in said negative feedback loop and a shunting path comprising a second transistor switch and means connecting the output signal of said rectifying means to said second transistor switch to control the mode thereof for reducing of the net feedback factor of said second network on closure of said second switch.

7. An amplifier circuit in accordance with claim 6, wherein said means for coupling a portion of said main amplifier signal into said second amplifier comprises said first network, thereby to assure that the voice-switching threshold remains independent of the gain of said main amplifier.

8. An amplifier in accordance with claim 6, further comprising means for controlling the rate of turn-on of said second transistor switch and also means for maintaining said second transistor switch in its on-mode for a predetermined time after removal of the signal from said rectifying means.

No references cited.

KATHLEEN H. CLAFFY, Primary Examiner

J. B. LEAHEEY, Assistant Examiner