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HIGH GAIN AMPLIFIER

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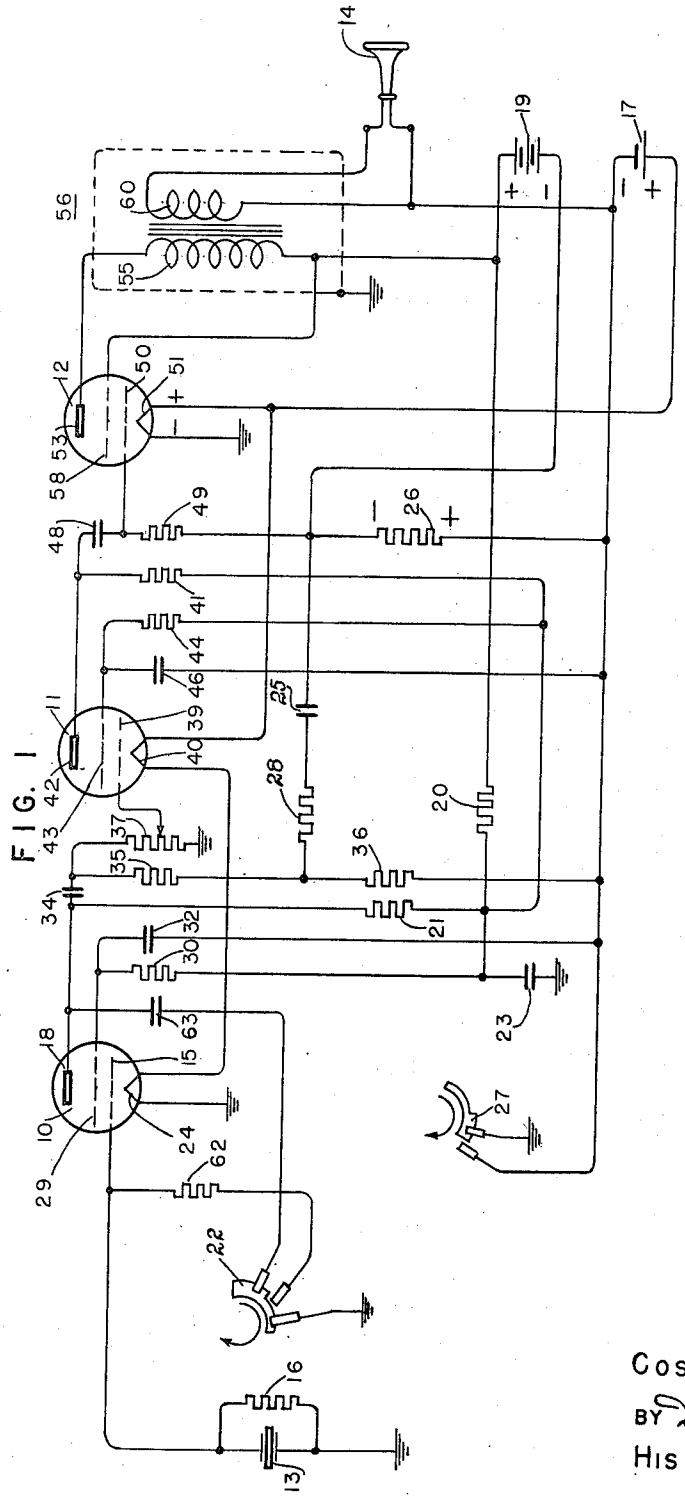


FIG. 1

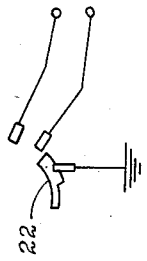


FIG. 4

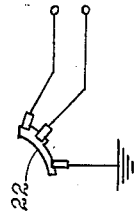


FIG. 2

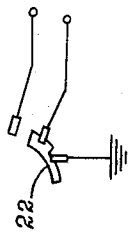


FIG. 3

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HIGH GAIN AMPLIFIER

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2 Claims. (Cl. 179—171)

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This invention relates to a high gain amplifier, and particularly to such an amplifier as is used in small radio or hearing aid apparatus.

It is desirable to make hearing aid apparatus of small size and with the least number of parts for purposes of convenient carrying and economy in manufacture. In such apparatus, input signals must usually be amplified greatly for accomplishing the purposes of the apparatus. Also it is usually desirable to make the amplification of the apparatus relatively independent of the magnitude of input signals. The desirable qualities of smallness are better realized when the amplification of each stage is high and when the number of stages is at minimum.

In the use of hearing aid apparatus, the user must bear a relatively great expense for replenishing the power supply. As a general rule, the more electron discharge devices used in the hearing aid circuit, the greater is the drain on the power supply. Also, it is desirable to incorporate a tone control in the hearing aid apparatus and this is usually accomplished by sacrificing some of the over-all amplification or gain realized in the hearing aid circuit; in general, a sacrifice of over-all gain or amplification is reflected as an increased drain on the power supply.

It is therefore an object of this invention to provide an improved small high gain amplifier stage and particularly one which produces linear amplification.

Another object of this invention is to provide an improved amplifier circuit having a tone control therein and requiring a minimum number of electron discharge devices.

Another object of this invention is to provide an improved high gain circuit requiring a small amount of space current.

A further object of the present invention is to provide an improved circuit in a hearing aid of the bone conduction type.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. This invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

Figure 1 shows an improved hearing aid circuit incorporating a high gain amplifier circuit which embodies the present invention; and

Figs. 2, 3 and 4 show a portion of the apparatus shown in Fig. 1 in various operating positions.

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In Fig. 1, there is illustrated an improved hearing aid circuit incorporating a first high gain amplifier circuit including an electron discharge device 10, a second cascade amplifier including electron discharge device 11 and a third cascade amplifier including electron discharge device 12. These three amplifiers successively amplify signals from microphone 13 and impress such amplified signals on a sound reproducing device or bone conduction unit 14 in linearly amplified form. A switch 22 for effecting tone control is interconnected with the device 10.

Sound waves impinging on microphone 13 are transformed into electrical variations in the main control electrode circuit of discharge device 10. The microphone 13 is preferably of the piezoelectric type as illustrated in Fig. 1. The device 10 amplifies electrical variations produced by microphone 13 and the amplified electrical variations are further amplified by electron discharge device 11 and electron discharge device 12 before being applied to the sound reproducer 14. One of the important features of this invention is the fact that sound waves impinging on microphone 13 are reproduced by sound reproducing device or bone conduction unit 14 in greatly amplified form and the degree of amplification is substantially independent of the magnitude of sound waves impinging on microphone 13 or signal voltage applied to the main control grid 15 or device 10.

Microphone 13, which produces electrical variations in response to sound waves impinging thereon, is connected between the main control grid 15 and the grounded filamentary cathode of discharge device 10. A grid leak resistance 16 is connected in parallel circuit relationship with microphone 13 to by-pass current around microphone 13 between control grid 15 and the cathode of discharge device 10. It is noted that substantially no grid current flows through resistance 16 since the grid 15 is at an average negative potential with respect to the positive cathode of device 10, such negative bias potential being provided by connecting grid 15 through resistance 16 and switch 27 to the grounded negative terminal of source 17 whose terminals are connected to the respective terminals of the cathode of device 10.

Electron discharge device 10 is of the screen grid type having its anode 18 connected to the positive terminal of a voltage source 19 through serially connected resistances 20 and 21, the junction of resistances 20 and 21 being connected to ground for currents of frequency in the audible range through condenser 23 so that substantially

all of the audio voltage appearing in the anode circuit of device 10 appears across the resistance 21, and resistance 20 serves as a voltage dropping resistance for the flow of continuous current supplied to anode 18 from source 19. The negative terminal of source 19 is grounded through serially connected resistance 26 and on-off switch 27, a continuous current path being thus formed to cathode 24.

Screen 29 of device 10 is connected for the flow of continuous current thereto to the positive terminal of source 19 through serially connected resistances 30 and 20, and continuous current flows from the positive terminal of source 19 through serially connected resistances 20 and 30, screen grid 29, cathode 24, ground, switch 27, and resistance 26 back to the negative terminal of source 19. Substantially no audio frequency voltage appears in this screen grid circuit, outside of device 10, a by-pass condenser 32 being connected between grid 29 and ground through switch 27.

Amplified audio frequency voltages appearing in coupling resistance 21 in response to voltages developed in microphone 13 are transferred to the control grid of the screen grid device 11 from the junction point of anode 18 with one terminal of resistance 21 through coupling condenser 34 and volume control resistance 37, of which one terminal is grounded and the adjustable tap is connected to the control grid 39. The ungrounded terminal of volume control resistance 37, connected to condenser 34, is connected serially through resistances 35 and 36 and switch 27 to ground. Cathode 40 of device 11 is connected to ground through cathode 24, and audio frequency voltages appearing between the tap on volume control resistance 37 and the grounded end thereof are applied to device 11 for amplification. A negative bias voltage exists between cathode 40 and grid 39 by reason of the voltage drop in cathodes 24 and 40.

Anode 42 of device 11 is connected with the positive terminal of source 19 through serially connected resistances 20 and 41, the junction point of resistances 20 and 41 being grounded for currents of audio frequency by condenser 23, which not only serves to by-pass audio frequency currents in the anode circuit of device 10 but also serves to by-pass currents in the anode circuit of device 11. Substantially all of the audio output voltage in the anode circuit of device 11 appears across resistance 41.

Screen grid 43 of device 11 is connected with the positive terminal of source 19 through serially connected resistances 20 and 44. Since the negative terminal of source 19 is connected to ground through resistance 26 and switch 27, and the cathode 40 is grounded through cathode 24, the combined screen grid and anode currents in device 11 flow through resistance 26. Screen by-pass condenser 46 is connected between screen grid 43 and ground through switch 27, so that the voltage of screen grid 43 does not change at frequencies in the audio range.

Amplified signal voltages developed across resistance 41 are impressed on control grid 50 of device 12 through coupling condenser 48, connected between anode 42 of device 11 and grid 50. Bias voltage and degenerative voltage are impressed on grid 50 through a resistance 49, connected between grid 50 and the negative terminal of source 19, one terminal of the cathode 51 of device 12 being grounded.

Anode 53 of device 12 is supplied with continuous current from the positive terminal of source 19 through the primary winding 55 of transformer 56. Since the negative terminal of source 19 is grounded through resistance 26 and switch 27, and one terminal of cathode 51 is grounded, a portion of the output voltage of device 12 appears across resistance 26. Screen grid 58 of device 12 is connected directly to the positive terminal of source 19 so that grid current flows from the positive terminal of source 19 through grid 58, cathode 51, ground, switch 27, resistance 26 and back to the negative terminal of source 19.

It is important to note that with the circuit arrangement thus far described, a signal applied to grid 50 is amplified in device 12 and such amplified signal has a fractional part thereof appearing across primary winding 55 and a fractional part thereof appearing across resistance 26, resistance 26 being unby-passed. That fractional part of the amplified signal which appears across winding 55 causes a current to flow in secondary winding 60 of transformer 56 and sound reproducing device or bone conduction unit 14 which is serially connected with winding 60. That fractional part of the amplified voltage appearing across resistance 26 is transferred, or fed back, to the grid-cathode circuit of device 11 in such phase and magnitude as to produce what is commonly referred to as regeneration without oscillation.

Such amplified signal voltages appearing across resistance 26 (having been produced in the output circuit of device 12) are transferred or fed back to the grid 39 of device 11 from one terminal of resistance 26 (whose other terminal is grounded through switch 27) through a condenser 25 and a resistance 28, serially connected between the ungrounded terminal of resistance 26 and a point between resistances 35 and 36.

It is evident that a signal applied to grid 39 of device 11 causes a portion of the resulting amplified signal voltage to appear across resistance 26. The resulting signal voltage drop across resistance 26 causes some degenerative action in the amplifying circuit comprising device 12, and causes a relatively large regenerative effect at grid 39.

It is an important aspect of this arrangement that space current flowing through resistance 26 produces a continuous bias potential between grid 50 and cathode 51 of device 12. This grid bias potential is thus provided without the use of a by-pass condenser in shunt to resistance 26 and without the sacrifice of any over-all gain which would have to be tolerated if the by-pass condenser were omitted and the degenerative action in device 12 allowed to reduce gain in device 12 without a corresponding increase in gain, here achieved by regenerative feedback through resistance 28 and condenser 25 to grid 39 of device 11. Stated otherwise, the omission of a by-pass condenser in shunt to resistance 26 saves much space required by its large bulk, betters the cleanness of amplification in device 12 by reason of degeneration therein, and produces greater over-all gain than with the by-pass condenser by reason of regeneration from the unby-passed resistance 26 to grid 39.

The voltage fed back from resistance 26 to control grid 15 of device 10 is made a minimum by the shielding action of screen grid 29. A minimum signal voltaage appears on screen grid 29 by reason of the filter sections respectively, including resistance 30 and condenser 32 and resistances 20 and 21 and condenser 23.

Cathode heating current for devices 10, 11 and

12 is supplied from source 17 by connecting one terminal of cathode 24 to a terminal of cathode 40, grounding the remaining terminal of cathode 24 and connecting the remaining terminal of cathode 40 to the positive terminal of source 17, the negative terminal of source 17 being grounded through on-off switch 27 so as to produce a current flow through the serially connected cathodes 24 and 40. Cathode 51 of device 12 has one of its terminals grounded and its other terminal connected to the positive terminal of source 17, the negative terminal of source 17 being grounded through on-off switch 27.

The control grids 15, 39 and 50, respectively, of devices 10, 11 and 12 are all biased negatively with respect to their associated cathodes 24, 40 and 51 so that substantially no continuous grid current flows from those grids in normal operation of the composite hearing aid circuit. Control grid 15 is maintained negative with respect to cathode 24 since heating current flowing through cathode 24 to ground causes the cathode 24 to assume an average positive potential with respect to ground, grid 15 being grounded through resistance 16. Also, the control grid 39 is maintained negative with respect to cathode 40 since heating current flowing through cathodes 40 and 24 to ground causes cathode 40 to assume an average positive potential with respect to ground and since grid 39 is grounded through resistance 37. Grid 50 is maintained negative with respect to its associated cathode 51 since heating current flowing from the positive terminal of source 17 through cathode 51 to ground causes the cathode 51 to assume an average positive potential with respect to grid 50. Grid 50, grounded through serially connected resistances 49 and 26, is also, as explained, maintained at a negative bias potential with respect to ground by the continuous voltage drop across resistance 26, of polarity indicated in Fig. 1.

It is thus evident that resistance 26, of suitable magnitude, is not only connected to maintain grid 50 at a desired negative continuous bias potential (and that without having a bulky by-pass condenser) but is also connected so as to feed back a signal voltage therefrom degeneratively to grid 50 of device 12 and regeneratively to grid 39 of device 11 through serially connected condenser 25 and resistance 28.

Purely by way of example, in an actual hearing aid circuit embodying the present invention, the magnitude of resistance 26 is 1,800 ohms, resistance 20 is 390,000 ohms, resistance 28 is 560,000 ohms, resistance 21 is 1 megohm, resistance 35 is 4.7 megohms, resistance 37 is 3 megohms, resistance 41 is 1 megohm, resistance 30 is 3.3 megohms, coupling condenser 25 is .0005 microfarad, resistance 36 is 470,000 ohms, condenser 32 is .01 microfarad, condenser 34 is .001 microfarad, condenser 48 is .001 microfarad, and condenser 23 is .05 microfarad. In such case, resistance 20 and condenser 23 are of sufficient magnitude to decouple resistance 26 from the grid circuit of device 10.

In any particular case, the relative amounts of regeneration in the circuit including device 11 and degeneration in the circuit including device 12 are dependent on frequency of the signal applied to grid 15 and, in a circuit having elements such as those described, an equal amount of overall regeneration and degeneration is present at approximately 180 cycles per second. The amount of regeneration increases substantially with frequency, so that in the useful audible range the

regeneration effect in the circuit exceeds the degeneration effect. Furthermore, such increase in regeneration at higher frequencies is advantageous, inasmuch as the high frequency response of the composite hearing aid circuit is increased in a range where most present day hearing aid circuits are deficient.

Another important feature of the present invention is that a four-position tone control arrangement is provided in combination with the regenerative amplifier circuit described, in which the position of such control has substantially no detrimental effect on the regenerative circuit described.

The tone control member 22 is movable to four different positions as shown in Figs. 1 to 4 to produce different tone effects.

Tone control member 22 serves to selectively connect either one terminal of tone control resistance 62 or one terminal of tone control condenser 63 or both of such terminals to ground, the remaining terminals of resistance 62 and condenser 63 being permanently connected respectively to grid 15 and anode 18.

In the position of tone control member 22 in Fig. 1, the tone control condenser 63 is connected between anode 18 and ground and high frequency components of the signal amplified by device 10 are attenuated. This corresponds to what is termed the "high cut" position.

In the position of tone control member 22 in Fig. 2, the tone control condenser 63 is connected between anode 18 and ground and tone control resistance 62 is connected in parallel circuit relationship to crystal microphone 13. In such case, the low frequency components of sound energy impinging on crystal 13 are applied in reduced form to the grid 15 and also the high frequency components of signal amplified in device 10 are attenuated. This position corresponds to the "high and low cut" position.

In the position of tone control member 22 in Fig. 3, tone control resistance 62 is connected in parallel circuit relationship to crystal microphone 13 and also condenser 63 is unconnected. In such case the low frequency components of sound energy impinging on microphone 13 are applied with more diminished amplitude on grid 15 of device 10 than the high frequency components of sound energy impinging on crystal 13. This position of member 27 corresponds to the "low cut" position.

In the position of tone control member 22 in Fig. 4, neither the tone control resistance 62 nor the tone control condenser 63 is inserted in operative relationship with respect to amplifying device 10 and consequently these two elements produce no tone effects on the components of sound energy reproduced by crystal 13. This position of control member 22 corresponds to the "normal" position.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this 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 this invention.

I claim:

1. In an amplifying circuit, a first discharge device having an input circuit, a screen electrode, an output anode, a cathode, and an output circuit, a second discharge device having an input

circuit coupled to the output of said first discharge device and having an output circuit, a third discharge device having a control grid and having an output circuit, a control circuit including said control grid coupled with the output circuit of said second device, a pair of serially connected impedances in the last mentioned output circuit whereby signals applied to the input circuit of said first device appear across said serially connected impedances in amplified form, a voltage source having a positive terminal arranged to supply continuous space current to each of said output circuits and to said screen electrode through one of said serially connected impedances, said one impedance being connected in said control circuit and arranged so that continuous space current flowing therethrough determines the continuous operating potential of said control grid, means arranged to couple an amplified signal voltage appearing across said one impedance to the input circuit of said second discharge device in regenerative relationship, and means arranged to prevent the transfer of signal voltage from said one impedance to said screen electrode of said first device, said last means including a common current limiting resistor serially connected in a common circuit from said positive terminal to said screen electrode and said anode, and two condensers serially connected between said output anode and said screen electrode, the junction point of said serially connected condensers being connected to said cathode thereby to utilize said current limiting resistor in a circuit doubly decoupling said screen electrode from said positive terminal.

2. In an amplifying circuit for amplifying signals in a band of frequencies, a first discharge device having an input circuit, a screen electrode, an output anode, a cathode, and an output circuit, a second discharge device having a control electrode coupled to the output of said first device and having an output circuit, a third discharge device having a control grid and having an output circuit, a control circuit including said control grid coupled with the output circuit of said second device, a pair of serially connected impedances in the last-mentioned output circuit whereby signals applied to the input circuit of said first device appear across said serially connected impedances in amplified form, a voltage source having a positive terminal arranged to supply continuous space current to each of said output circuits and to said screen electrode through one of said serially connected impedances, said one impedance being connected in said control circuit and arranged so that continuous space current flowing therethrough determines the continuous operating potential of said control grid, a condenser, a resistance serially connected with said condenser, means including said resistance and condenser arranged to couple an amplified signal voltage appearing across said one impedance to the control electrode of said second discharge device in regenerative relationship, a filter circuit and means including said filter circuit arranged to prevent the transfer of screen voltage from said one impedance to said screen electrode of said first device, said last means including also a common current limiting resistance serially connected in a common circuit from said positive terminal to said screen electrode and said anode, and two condensers serially connected between said output anode and said screen electrode, the junction point of said serially connected condensers being connected to said cathode thereby to utilize said current limiting resistance for a circuit doubly decoupling said screen electrode from said positive terminal.

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