Jan. 19, 1943. H. B. SHAPIRO 2,308,550

AMPLIFYING HEARING AID

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Fig. 1

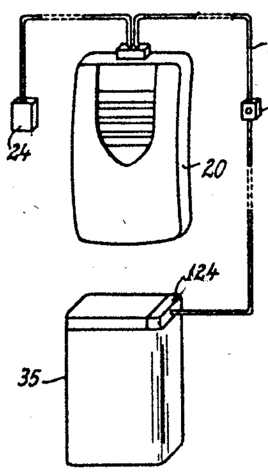


Fig. 2

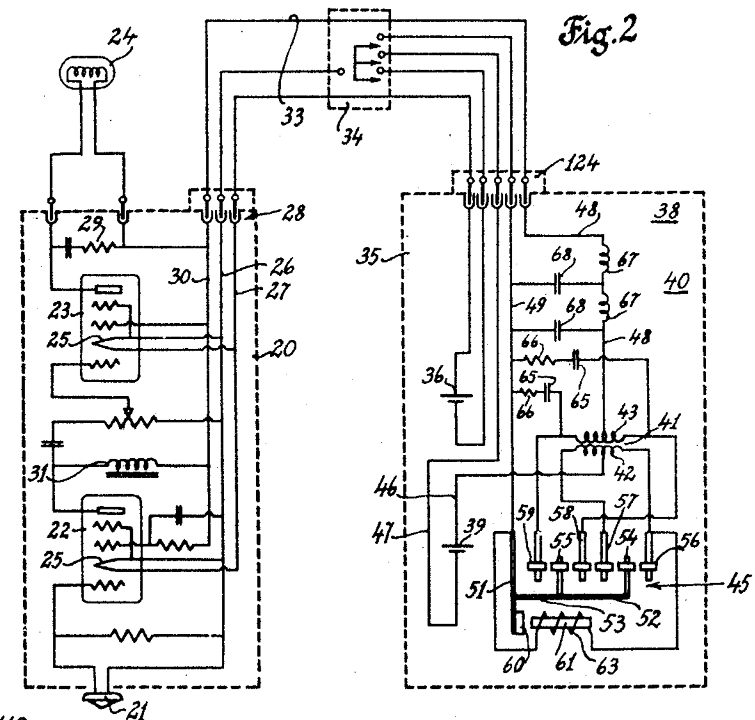


Fig. 5

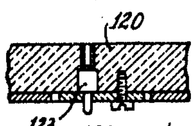


Fig. 3

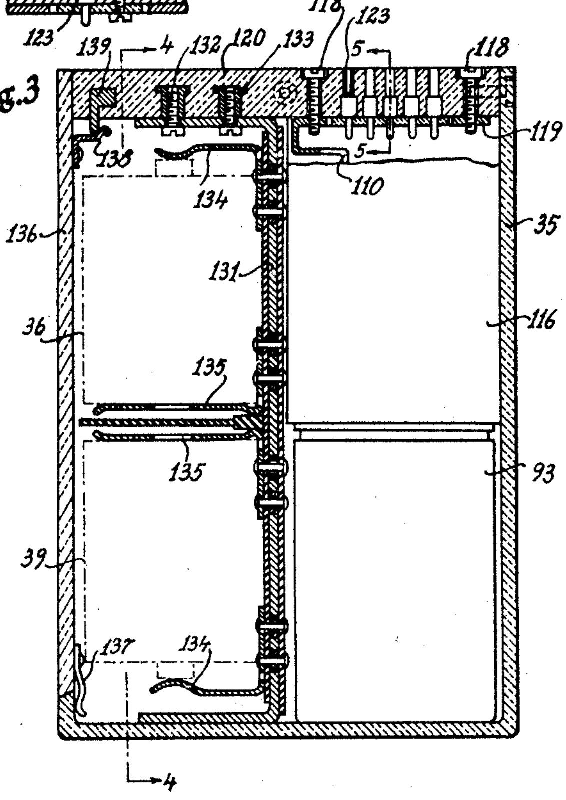
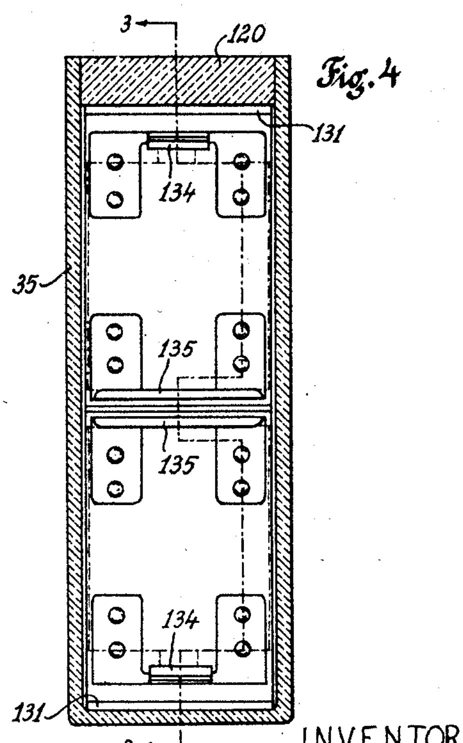


Fig. 4



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AMPLIFYING HEARING AID

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Fig. 6

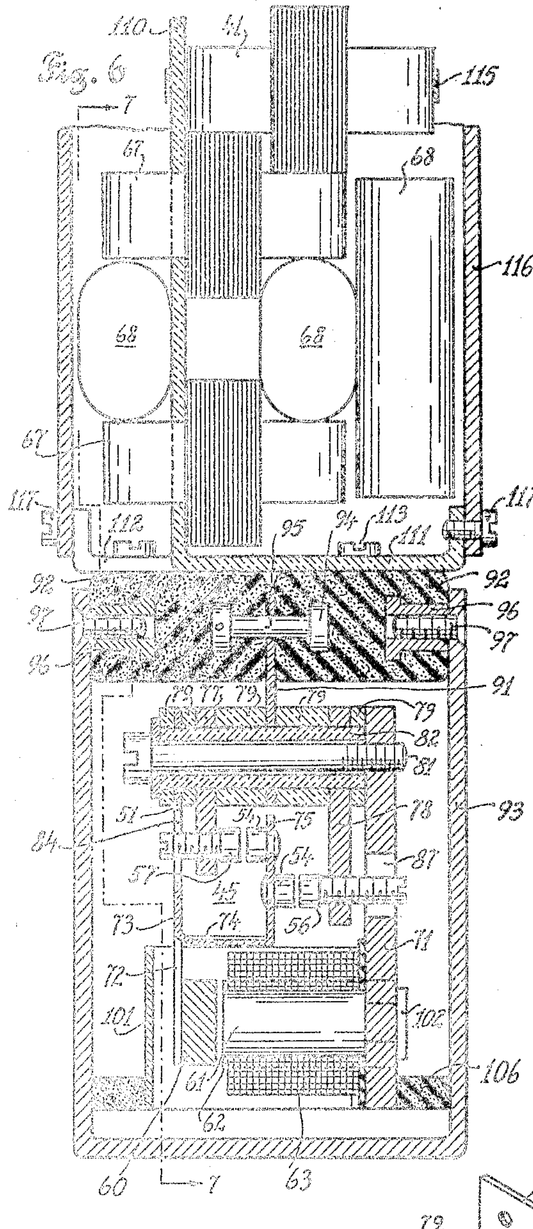
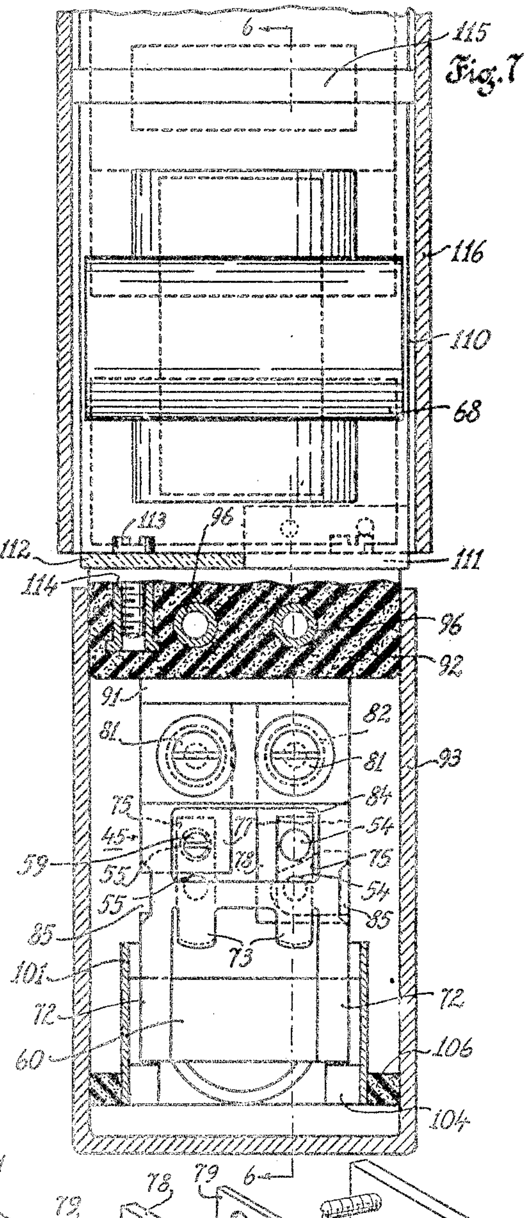


Fig. 7



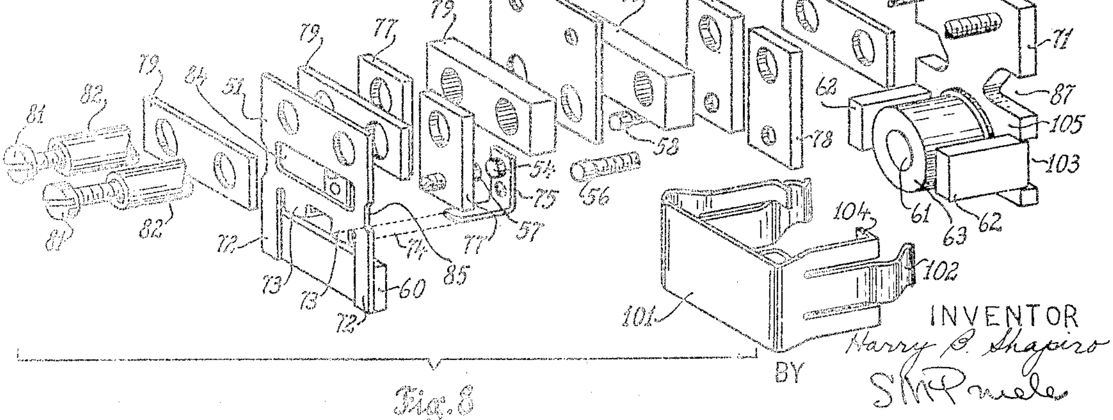


Fig. 8

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Fig. 11

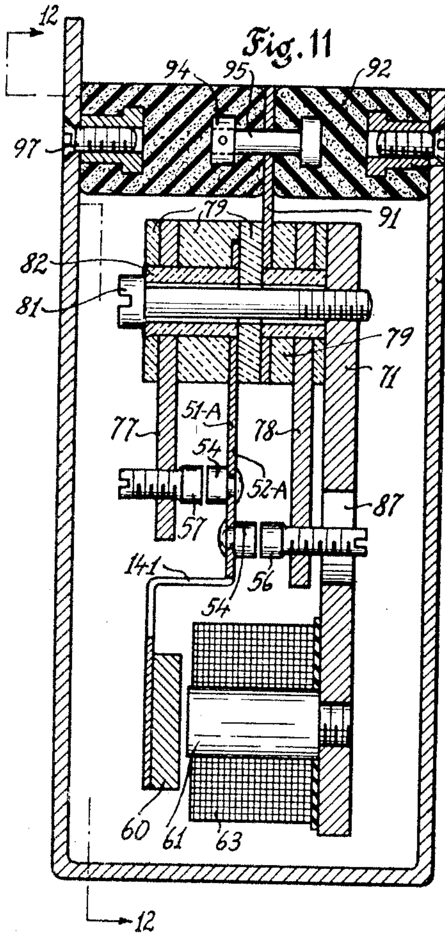


Fig. 12

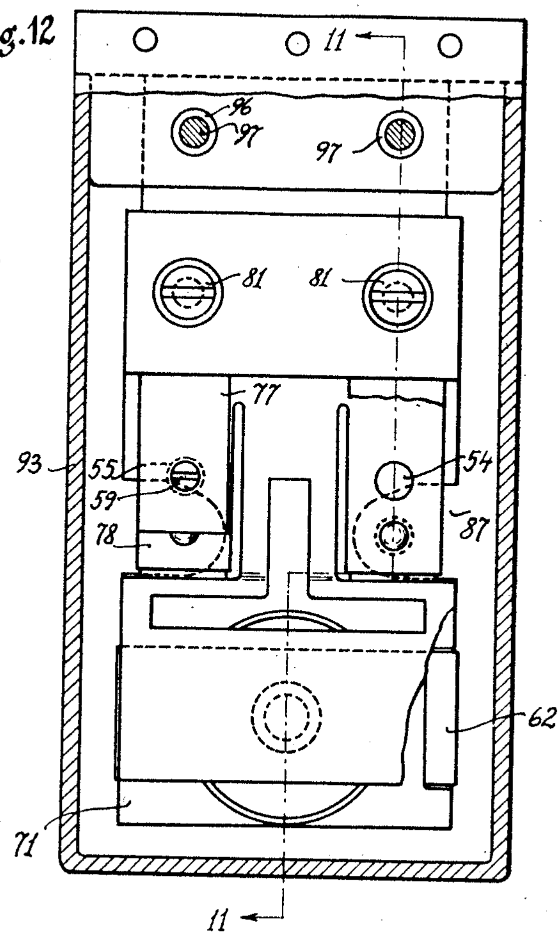


Fig. 13

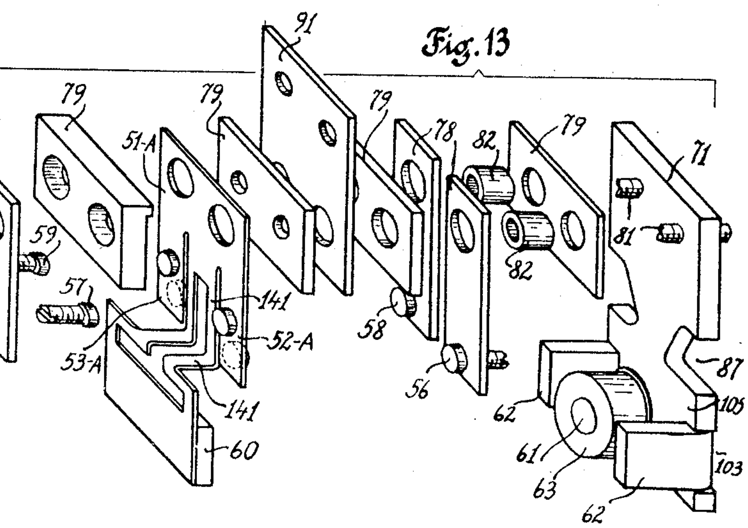


Fig. 9

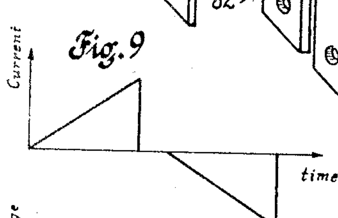
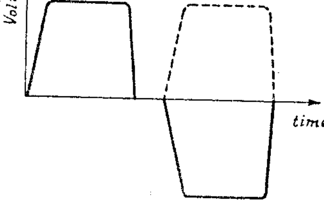


Fig. 10



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Patented Jan. 19, 1943 2,308,550

UNITED STATES PATENT OFFICE

2,308,550

AMPLIFYING HEARING AID

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Application July 18, 1940, Serial No. 346,125

4 Claims. (Cl. 179—107)

This application is a continuation-in-part of my copending application Serial No. 338,586, filed June 3, 1940.

This invention relates to amplifying hearing aids, and it has among its objects an electron tube amplifier hearing aid arrangement using a voltage transforming and rectifying vibratory contactor arrangement for transforming a low voltage from a direct current source, such as a single battery cell, into a relatively high voltage required for operating the electron tube amplifier.

Among the objects of the invention is an improved voltage-transforming and rectifying vibratory contactor arrangement having its elements so designed, arranged and correlated that they may be compressed into an extremely small structure operating with a sufficiently high efficiency so that it may be used in lieu of dry cell batteries for energizing the anode circuits of electron tube amplifiers, such as used in hearing aids, which must be kept small enough to be suitable for inconspicuous wear on the body of the user.

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

Fig. 1 is a perspective view illustrating the elements of a wearable electron tube hearing aid using a voltage transforming arrangement of the invention;

Fig. 2 is a circuit diagram illustrating the cooperative relationship of the elements of the hearing aid of Fig. 1;

Fig. 3 is a cross-sectional view through a power supply unit, such as shown in Figs. 1 and 2;

Fig. 4 is a transverse cross-sectional view along line 4—4 of Fig. 3;

Fig. 5 is a detailed view along line 5—5 of Fig. 3;

Fig. 6 is a vertical cross-sectional view through a voltage transforming arrangement of the invention;

Fig. 7 is a cross-sectional view along line 7—7 of Fig. 6;

Fig. 8 is an exploded view of the vibratory contactor mechanism of Figs. 6 and 7;

Fig. 9 is a curve diagram indicating the rate of rise of the periodic current impulses in the primary transformer winding;

Fig. 10 is a curve diagram indicating the voltage induced by the primary current impulses in the secondary transformer winding and the effect of the rectifying action; and

Figs. 11, 12 and 13 are views similar to Figs. 6, 7 and 8 illustrating a modified form of such vibratory contactor mechanism.

In my copending application Serial No. 294,649, filed September 13, 1939, are described electron tube amplifiers designed for use as a part of a wearable hearing aid, all the elements of which must be small enough so that they may be worn hidden in operative condition on the body of the user. The general arrangement of one such electron tube amplifier is shown in Figs. 1 and 2.

In a compact flat casing 20 small enough for inconspicuous wear, for instance, in the vest pocket of the user, is mounted a diaphragm-driven Rochelle salt crystal microphone 21 which drives a voltage-amplifier electron tube 22, the output of which is amplified by a power amplifier tube 23 that supplies its output to a hearing aid receiver 24 which is small enough for inconspicuous wear on the head of the user.

In the form shown, the two amplifier tubes are of the pentode type and they have filamentary cathodes 25 which are energized in parallel through two leads 26, 27 extending from plug terminals 28 in the wall of the casing. The voltage amplifying stage is coupled to the power amplifier stage by a coupling inductance 31 and is arranged and designed in the way disclosed in my copending application Serial No. 294,649, filed September 13, 1939, so that the voltage amplifier stage shall operate with a gain of more than 100 over the frequency range between 500 and 4000 cycles sufficient to produce only with one additional power amplifier stage a power output that is substantially flat within plus and minus three decibels over the principal speech frequency range, and is sufficient to drive a standard bone conduction receiver.

If an electromagnetic receiver 24 having a high impedance winding is used, its winding is connected, in the way shown, directly in the output circuit of the power amplifier tube. A response control arrangement 29 may be combined with the other elements of the amplifier in the way described in my application Serial No. 294,649, so as to make possible selective control of the amplification in the different parts of the speech frequency range in accordance with the needs of the user.

The anode or plate circuits of the two tubes 22, 23 are supplied through an anode supply lead 30 connected to another terminal of the amplifier unit. The screen grids of the two tubes are suitably connected to the anode lead 30 so as to maintain them at their required operating potential. The cathode supply leads 26, 27 and the anode supply lead 30 are connected through leads of a multi-conductor cord 33 and contacts of a switch 34 to an electric power supply unit, in the form of a flat compact casing 35, which is small enough for hidden, inconspicuous wear on the body of the user, and houses a small dry cell battery 36 which supplies the cathode leads 26, 27 and a source of power which supplies direct current of proper voltage and polarity to the anode supply lead 30 of the amplifier 20.

As disclosed in my copending application Serial No. 294,649, filed September 13, 1939, a hearing aid amplifier of the foregoing type will deliver the required output to a standard bone conduction receiver when operating with a very low anode voltage. Most of the commercially sold hearing aid amplifiers of the foregoing type operate with small compact dry cell B batteries supplying an anode voltage of only 24 volts and having a useful operating life of several hundred hours. In less severe cases of deafness, a B battery delivering a voltage of only 12 volts is sufficient.

Instead of employing a dry cell battery pack for supplying the anode circuits of the amplifier, the hearing aid amplifier of Figs. 1 and 2 uses a voltage transforming and rectifying vibratory contactor arrangement 38, small enough for housing in the flat compact casing 35 of the power unit and operated by a small dry cell 39 for supplying direct-current voltage required for energizing the anode circuit of the amplifier.

As shown diagrammatically in Fig. 2, the voltage transforming and rectifying contactor arrangement 38 is similar in its general arrangement to those used in radios. It comprises a step-up transformer 41 having a center tapped primary transformer winding 42 and a center tapped secondary transformer winding 43 which is combined with a vibratory contactor mechanism 45 to periodically send, from the low voltage leads 46, 47 which are connected to the battery cell 39, oppositely directed current impulses through the two halves of the primary transformer winding 42 and to rectify the alternating voltage induced by the primary current impulses in the secondary transformer winding 43 and impress the rectified voltage on two high voltage leads 48, 49 to which the anode supply circuit of the amplifier 20 is connected.

The vibratory contactor mechanism 45 has a vibratory spring reed 51 carrying on two reed projections 52, 53 oppositely facing reed contacts 54, 55 cooperating with two sets of contacts 56, 57 and 58, 59 which are connected to the ends of the primary transformer winding 42 and secondary transformer winding 43, respectively.

To the free end of the reed 51 is secured a magnetic armature 60 which is driven by an electromagnet 61 having an actuating winding 63 connected between the reed 51 and one of the ends of the primary transformer winding 42, so that when the circuit from its operating cell 39 is completed by the closure of switch 34, the magnet winding 62 is energized, operating the reed to flex and short circuit at its contacts 54, 56 the magnet winding 63, thereby releasing the reed to swing in opposite direction, whereupon the magnet 61 is again energized. This sequence of operations is continuously repeated, and the reed 51 is vibrated as long as the switch 34 completes the circuit from the battery cell 39.

The reed contact 54 forms in association with its contacts 56, 57 a set of primary impulse contacts which close and open periodically during each vibrating cycle of the reed, to send oppositely directed intermittent current pulses from cell 39 through the two halves of the primary transformer winding 42, so as to induce in the secondary transformer winding an alternating voltage. The reed contact 55 forms in association with its periodically closing and opening contacts 58, 59 a set of secondary rectifying contacts which rectify the alternating voltage induced in the secondary transformer winding 43 and impress it in rectified form on the high voltage leads 48, 49 and therethrough on the anode circuits of the amplifier.

In order to suppress sparking when the vibratory reed contacts break currents in the associated circuits, each half of the secondary transformer winding 43 is bridged by a condenser 65 with or without a series resistance 66 designed to operate in the way described in U. S. Patent 1,296,269. A filter formed of series connected iron-core inductances 67 and shunt condensers 68 is interposed in the high voltage output leads 47, 48 to smooth out the rectified current pulsations impressed on the high voltage leads 48, 49 and to deliver to amplifier terminals of the anode supply lead 30 and the cathode lead 26 a smooth direct-current voltage of the required polarity.

Vibratory contactor voltage transforming and rectifying contactor arrangements of the foregoing type have been used for many years in battery-operated radio sets. In accordance with the invention, the elements of such voltage transforming and rectifying contactor arrangements are designed and arranged to operate so that they may be compressed within an extremely small structure which is efficient in operation and is able to supply with a relatively small drain from a low voltage source, such as a single dry cell battery of 1.5 volt, a relatively high voltage direct current required for the anode circuits of wearable electron tube amplifiers, such as used in hearing aids.

One form of such transforming and rectifying contactor arrangement exemplifying the invention is shown in detail in Figs. 6 to 8. The electromagnet 61 is made in the form of an elongated core member secured, as by threading or riveting, to a mounting plate 71 of magnetic material on which the entire vibratory contactor mechanism is mounted, and having two pole leg extensions 62 on the two sides of the core pole. The reed 51 is stamped from a sheet of electrically conducting spring metal and has at its free end two arms 72 to which the armature 60 is suitably secured, as by soldering or welding.

On the intermediate freely vibrating portion of the reed 51 extending between the two armature arms 72 are formed two contact-operating reed arm projections 73 which have bent intermediate sections 74 extending perpendicularly away from the plane of the reed terminating in reversely bent overhanging reed portions extending parallel, but in opposite direction to the armature arms 72 of the reed. On the overhanging end portions 75 of the two contact arms 73 of the reed are mounted the oppositely facing vibratory reed contacts 54, 55, respectively. Although the contacts 54, 55 may be made double faced, it is easier to mount them slightly offset on overhanging reed arm portions 75, as shown.

The oppositely facing reed contacts 54 are arranged to cooperate with the contacts 56, 57 shown fixedly held on the free ends of supporting arms 77, 78 aligned on the opposite sides of the reed contacts 54, so as to close and break their contacts during the operation of the reed. The other set of contacts 58, 59 cooperating with the other reed contacts 55 are held by a similar set of supporting arms 77 aligned on opposite sides of the reed contacts 55.

The reed 51 and the two sets of supporting arms 77, 78 for the two sets of stationary contacts are assembled in alignment with the reed and its contact arms 73 between insulating spacers 79 and clamped to one end of the mounting plate 71 by two bolts 81 which are insulated from the metallic conducting portions of the reed 51 and the contact supports 77, 78 by insulating sleeves 82.

By arranging the vibratory contactor mechanism with a vibratory reed which drives two reed projections carrying the vibratory reed contacts in a plane offset, but substantially parallel to the plane of the reed and its armature, it is possible to compress its overall volume into a fraction of the volume heretofore considered necessary for such vibratory contactor mechanism. By making each reed contact arm 73 with an intermediate section 74 extending in the direction of the motion of the reed, substantially perpendicularly to the surface of the reed portions on which the vibratory forces are exerted by the driving magnet 61, the overhanging reed arm portions 75, which extend parallel to the armature arms 72 of the reed, are forced to follow accurately the motion of the armature and to vibrate in unison with it, except for the intervals during which the reed contacts are held closed while the inertia or momentum of the armature carries it to the end of its full vibratory amplitude.

By giving the intermediate perpendicularly bent portion 73 of the reed contact arm 74 a transverse concavo-convex cross section, in the way shown in Figs. 5 and 6, it is stiffened to resist bending out of the position of perpendicular alignment to the main portion of the reed 51 and to its free end portion 75 carrying the vibratory reed contacts.

Figs. 6 and 7 of the original drawings show in an enlarged 3:1 scale the actual dimensions of a practical contactor mechanism of the invention. The reed 51 is 11/16 of an inch long, its armature portion is 5/8 and its clamping portion is ½ of an inch wide. The mounting plate 71 is 11/16 of an inch long and 5/8 of an inch wide. The entire vibratory contactor mechanism has overall dimensions of about 11/16 x 5/8 x ½ of an inch.

The width and the free length of the armature arms 72 of the reed and the height and width of the opening 84 and depression 85 formed in the reed are so proportioned as to assure that its stiffness, or resiliency, and its vibratory masses are so distributed that it vibrates in a stable operating condition. Operation of such vibrator with a vibrating frequency in the range between about 100 and 200 cycles gave good results.

The armature 60 of the vibratory reed forms with the E-shaped poles 61, 63 of the driving electromagnet an efficient magnetic system including a magnetic gap across which the armature vibrates with a variable gap of the order of 0.030 of an inch, requiring only a fraction of the power that would be needed in operation with a variable area magnet system generally used in such arrangements. Operation with a variable length gap is made possible by making the vibratory contacts carried by the reed contact arms 73 light.

The gap distance between the armature and the pole faces of the driving magnet structure may be adjusted either by threadedly mounting the magnet pole piece 61 on the mounting plate 71 or by interposing thin shims under its clamped end or by slightly bending the reed.

In adjusting the gap spacing, the driving magnet 61 is energized from the D. C. source, such as the dry cell 39, having the required driving voltage, and the armature is brought just enough towards the pole face of the driving magnet as to cause it to swing towards the pole face and bring about its periodic vibratory motion in the way described hereinabove.

The two sets of stationary contacts 56, 57 and 58, 59 have threaded shanks held in threaded holes of the substantially rigid supporting arms 77, 78, so as to make it possible to adjust them in balanced positions in relation to their associated vibratory reed contacts. Threads of a fine pitch are used to facilitate fine adjustment of the contact positions. As the armature swings from its neutral position to the one or the other end point of its vibratory path, it is essential that its vibratory contact comes into good positive contact engagement with the stationary contact towards which it moves, and that this positive contact engagement is maintained during a large part of its motion in the region towards the end point of its path and back therefrom until it reaches the position in which it breaks the previously made contact as it approaches its neutral position on its opposite half of its swing from the neutral position.

The overhanging reed arm portions 75 which carry the vibratory reed contacts and the portion of the reed arm 73 which is parallel thereto are proportioned to serve as buffers which are bent by the momentum of the armature until it is gradually stopped and then gradually accelerated in opposite direction by the energy stored in the bent buffer portions of the contact arm 73 as well as in the flexed armature arm 72 of the reed 51. The momentum of the armature is thus utilized to maintain, in conjunction with the buffer action of the contact arm 73—75, positive contact engagement of its two pairs of vibratory contacts during a large part of each half vibratory cycle.

In addition, the flexing portions of the contact arms 73 with the contacts carried on their overhanging end portions 75 are designed to have a sufficiently higher resonant frequency than that of the vibrating system formed by the armature, and its vibratory reed support, as to assure that they follow the motion of the reed and maintain good chatter-free positive contact with the cooperating stationary contacts from the moment the contact is made until it is broken. The adjustable mounting of the sets of stationary contacts 56, 57 and 58, 59 makes it easy to secure their proper positioning in relation to the vibratory reed contacts without regard to the critical adjustment of the armature in a position of most efficient operation at a variable gap length from the pole faces of the driving magnet.

This adjustable mounting of the stationary contacts 56, 57 and 58, 59 makes it also easier to secure efficient voltage transforming and rectifying action.

In order to be suitable for use as a direct current supply for the anode circuits of a wearable electron tube amplifier, operating with a gain of about 80 decibels, such as used in hearing aids, a voltage transforming and rectifying contactor mechanism of the type described above must meet the following requirements:

It should be able to supply from a D. C. source, such as a battery cell of about 1.5 volts an output of about 15 milliwatts direct current at a voltage of about 60 volts with an efficiency of at least 50%, and its noise output should be not more than 20 decibels above the threshold of normal hearing.

In the voltage transforming and rectifying contactor arrangement of the invention, such efficiency is secured by so adjusting the stationary vibrator contacts 56, 57, 58, 59 in relation to the vibratory contacts 54, 55 and so designing and correlating the circuit elements interconnected with its output transformer and the elements of the vibratory reed contactor that upon the closure of the primary contacts, a direct current which rises substantially linearly with time is sent through its primary transformer winding; that the primary contacts open as soon as the substantially linear rise of the primary current ceases; that the secondary contacts close sufficiently soon after the closure of the primary contacts to assure that the rectified energy flow from the secondary winding of the load circuit shall take place substantially during the entire period the primary contacts are closed; and that the secondary contacts are opened sufficiently soon, at the time, or immediately before the opening of the primary contacts, to substantially prevent back flow of energy from the filter circuit or the load, toward the secondary transformer winding.

Neglecting the transients, the curves of Fig. 9 show the general form of the successive current impulses which are produced by the adjusted vibratory reed contacts in the two halves of the primary transformer winding, and the full line curves of Fig. 10 show the alternating voltage induced by the primary current pulses in the secondary transformer winding. By adjusting the secondary windings of the rectifier contacts of the vibratory contactor mechanism, substantially full rectification of the alternating current may be secured in the way indicated by the succession of full line and rectified dotted line half waves of the voltage impressed on the high voltage leads 48, 49. With such efficient operation of the voltage transforming and rectifying contactor mechanism, a relatively small filter occupying not more space than the contactor mechanism is able to supply about 15 milliwatts or even more smooth direct current at a voltage of about 60 volts.

In order to secure such operating conditions, the load circuit including the filter must be designed so that during the period when the primary contacts are closed the inductance and resistance of the load circuit, as are reflected in the primary side of the step-up transformer 41, shall cause the current flowing into the primary transformer winding to rise substantially linearly with time throughout the period during which the primary contacts remain closed, and the contacts must be adjusted to open at the point when the current ceases to rise.

As seen from Figs. 6 to 8, the opening 84 provided in the vibratory reed 51 not only serves to give the reed the desired stiffness characteristics, but also provides access to the slotted rear ends of the threaded shanks of the contacts 56 to 59 for enabling adjustment of their contact positions. Similarly, the mounting plate 71 has formed therein cutouts 87 through which the slots in the rear ends of the shanks of the contacts 56 to 58 may be reached for adjusting their contact positions.

In order to prevent transmission of vibrations from the vibrating mechanism to the exterior, the vibrating mechanism is suspended freely on a leaf spring member 91 extending from a mounting block 92 suitably secured within the top of a sound-proof casing 93. In the form shown, the mounting block 92 is formed of two rectangular members of resilient vibration absorbing material, such as rubber, Neoprene or Vinylite, having embedded therein, as by molding, two anchor heads 94 of a pin 95 on which the inner end of the leaf spring 91 is held. This arrangement assures that the vibrating forces exerted by the vibratory mechanism on its yielding supporting block 92 subjects the latter to shear, thus assuring efficient absorption and suppression of the vibratory forces.

The leaf spring 91 is held clamped between the insulating spacers 79 at a position in which the vibratory forces of the vibrating system balance each other so as to reduce to a minimum and render substantially negligible the vibratory forces transmitted to the support 92.

In two sides of the vibration absorbing block 92 facing the casing 93 are embedded inwardly threaded bushings 96 for receiving the threaded shanks of flat head screws 97 which clamp the edges of the casing 93 to the mounting block 92.

In addition, the interior or the exterior of the casing walls 93 are lined with a layer or layers of sound absorbing material, not shown. The unsupported end of the vibrating mechanism 45 with its magnetic driving structure may hang freely supported within the casing 93. In order to assure that the armature cannot be disturbed in the event the freely suspended end of the vibratory mechanism hits against a casing wall, a U-shaped protecting clip 101 is clamped over the armature end of the mechanism 45. The clip 101 has two arms with central inwardly bent latch projections 102 fitting and interlockingly engaging the recesses 103 formed at the junction of the mounting plate 71 with its legs 62, the center of the clip 101 being held spaced from the armature by inwardly bent stop members 104 engaging the facing surface portions 105 of the mounting plate 71 on both sides of its pole legs 86. If desired, a collar 106 of highly yieldable material, such as sponge rubber, may be placed around the clip 101 and the rear portion of the mounting plate against which it is held so as to serve as a stop in the event the suspended contactor mechanism 45 is thrown against a wall of the casing.

The contactor leads from the circuit elements of the contactor mechanism may be suitably led through the body of its supporting block 92 and interconnected on the exterior with the transformed winding 41, the filter choke coil 67, filter condenser 68 and the other elements interconnected with the high voltage leads 48 and 49.

As shown in Figs. 6 and 7, the step-up transformer 41, the filter inductances 67, and the other elements of the filter circuit are mounted on a bracket 110 of metal, for instance, having bottom legs 111, 112 which are secured, as by screws 113, to bushing inserts 114 embedded in the resilient vibration absorbing body of the supporting block 92 of the vibrator mechanism 45. The mass of the vibration absorbing body 92 interposed between the vibrating mechanism housed in the casing 93 and the elements of the filter mechanism carried on the bracket 110 is sufficiently large and so arranged as to prevent propagation of the vibrations to the elements mounted on the bracket. By using magnetic core inductances of the type described in my copending application Serial No. 294,649, filed September 13, 1939, having a core cross section of only 1/16 of one square inch and having overall core dimensions of about 3/4 x 3/8 x 1/8 of an inch, a very effective filtering action will be secured with a filter unit using only two such magnetic core inductances and occupying together with all other elements associated with the voltage transforming, rectifying and filtering arrangement a space of only about 1½ x 1½ x 3/4 inches.

As shown, the several elements associated with the filter and the output leads 48, 49 are suitably secured, as by bands 115, to the upstanding bracket wall 110. After mounting in place, the elements mounted on the bracket may be enclosed in a shield 116 of magnetic material, formed, for instance, of two parts which are clamped in position by flat head screws 117 to flanged edge portions of the bracket legs 111, 112. The leads extending from the flat contactor mechanism into the space above its mounting block 92 may be suitably interconnected with the elements of the filter mounted on the bracket in the way shown in Fig. 2.

As shown in Figs. 3 to 5, the contactor mechanism and the filter assembly may be suitably secured to the underside of a mounting block 120 forming a cover of the flat compact casing 35 in which the entire arrangement is mounted, for instance, by screws 118 clamping a bracket arm 119 to the cover 120. The leads to the transforming and rectifying arrangement may be suitably connected, as by soldering, to the inwardly projecting tips of socket members 123 mounted in suitable holes of the cover block 120 for receiver plug pins of a plug 124 through which the circuit connections to the amplifier unit 20 are completed.

The terminal sockets 123 may be of the type described in Figs. 6 to 9 of my copending application Serial No. 294,649, filed September 13, 1939, and may be arranged in the form of a separate socket secured to the upper bracket arm 119, all mounted together with it as a unit in its position on the cover 120. In the form shown, the upper bracket arm 119 has a hole into which the tips of the socket terminals 123 project for soldering the leads from the interconnected elements of the transforming, rectifying and filtering arrangement supported by the bracket 110, before its shield is secured in place thereon. The shield 116 is designed so that it may be formed as an integral unit and slipped down over the vibrator casing 93.

The two battery cells 36, 39 are likewise arranged to be held on a bracket 131 of metal, for instance, having an upper arm secured, as by screws 132, to the threaded bushing 133 embedded in the cover block 120 of the casing. On the downwardly extending bracket 131 are insulatingly mounted spring contact members 134, 135 arranged so that a standard dry battery cell may be quickly inserted into its operating position or removed therefrom, the contact members being suitably interconnected with the other circuit elements in the way shown in Fig. 2. The batteries may be quickly reached for removal or replacement by providing the casing with a removable end wall section 136 which is held in its position by two catch springs 137 engaging the adjacent wall portion near the bottom of the casing and two snap springs 138 which engage projecting ends of interlocking members 139 embedded in the molded body of the casing cover 120 so that by a pull on the end wall 136, it may be removed to expose the battery cells and by swinging it back on its bottom catch springs 137 its snap spring 138 will lock it back in closed position.

The switch unit 34 may be of the slider type, and may be mounted on the amplifier casing in the way shown in my copending application Serial No. 294,649, filed September 13, 1939, or it may be mounted either on the cover wall 120 of the power unit 35, or, as shown in Figs. 1 and 2, it may be combined with the cord at a point where it can be readily reached by the hand of the user, for instance, by providing it with a clip for holding it in the desired place.

In Figs. 11, 12 and 13 is shown an alternative form of a vibratory contactor mechanism of the invention. Its elements are similar to those shown in Figs. 6 to 8. Its vibratory reed 51A carries its armature 60 on a central arm 141 which is offset relatively to the portion from which its two vibratory contact arms 52A, 53A extend. Alternatively, its central armature bearing portion 141 may be formed into contact arms, such as 52A, and its outer two contact arms may be bent to support the armature 60 in the offset position shown, the intermediate perpendicularly bent portions 142 being stiffened as at 74 in Figs. 6 to 8.

The contactor mechanism of Figs. 11 to 13 occupies somewhat more space than that of Figs. 6 to 8. By mounting the armature on portions of the vibratory reed which are offset relatively to the contact arms 52A, 53A of the reed, such vibratory contact mechanism may be compressed into a very small size, only slightly larger than that described in connection with Figs. 6 to 8.

In order to prevent oxidation of the vibratory contacts, the contactor mechanism may be suspended in a hermetically closed vessel which is filled with an inert gas, such as nitrogen. Metal vessels, such as those used for metal vacuum tubes, or glass vessels, may be used as such enclosures.

When using a glass for such enclosure, two or three strong supporting wires may be sealed in a glass press and the innner ends of the supporting wires may be held clamped by the bolts 81 of the vibrating mechanism, so as to support it in a freely vibrating condition within the gas enclosing vessel.

The leads for completing the electrical circuit connections to the elements of the contactor mechanism are likewise sealed in the press, the inner ends of the leads being provided with loose end portions so that they are not subjected to any strain. To prevent the suspended portion of the contactor mechanism from breaking the glass walls, a metal clip which is placed around its vibrating armature may be provided with helical buffer springs extending toward the wall so as to prevent direct contact of the vibrating mechanism with the wall of the casing.

Instead of making the reed with offset portions as shown, all the elements may be made and aligned in the same plane, in which case the contactor mechanism is slightly increased in depth without sacrificing its operating advantages.

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

I claim:

1. In a wearable hearing aid, in combination: a flat amplifier unit having a case small enough for inconspicuous wear on the body of the user; an electron tube amplifier structure all the elements of which are small enough so that they are mounted within said case and include at least one voltage amplifier stage and one power amplifier stage each having a cathode heating element and anode circuit elements; a microphone small enough so that it is mounted within said case while exposed to sound propagated through the air surrounding the case; a set of amplifier terminal elements mounted on a wall portion of said case and circuit interconnections within said case for interconnecting said microphone unit and said terminal elements with the elements of said amplifier structure so as to impress the amplified output of said microphone on certain amplifier terminal elements; some of said amplifier terminal elements constituting cathode supply terminals for supplying heating current to said cathode heating elements and some of said amplifier terminal elements constituting anode supply terminals for supplying operating energy to said anode circuit elements; a receiver small enough for inconspicuous wear by the user and cord leads from said certain amplifier terminal elements to said receiver for supplying thereto the amplified output of said microphone; a structurally flat power unit small enough for inconspicuous hidden wear on the body of the user having two compartments and a power supply cord lead unit having cord leads extending from the power unit to the cathode and anode supply terminals of said amplifier unit; a cathode supply cell unit and anode supply cell unit within one compartment of said power supply unit; said cathode supply cell unit being connected through some of said power supply leads to the cathode supply terminals of said amplifier case; a voltage changing arrangement within the other compartment of said power supply unit and connected to said anode supply cell unit; said voltage changing arrangement including a vibratory contactor aggregate and a transformer so designed and correlated and so interconnected between said anode supply cell unit and some of said power supply leads as to cause said contactor to periodically send substantially linearly rising current impulses from said anode supply cell unit through the primary windings of said transformer for inducing a relatively high alternating voltage of substantially rectangular wave shape in the secondary windings of the transformer, and to cause the contactor to rectify the induced alternating voltage and to impress the so rectified voltage on the power supply leads connected to anode supply terminals of said amplifier; and switch means forming part of one of said units and including a single movable grip member actuable between a position in which the circuit connection to said anode supply cell unit and the circuit connection to said cathode supply cell unit are broken and a position in which both of said circuit connections are established.

2. In a wearable hearing aid, in combination: a flat amplifier unit having a case small enough for inconspicuous wear on the body of the user; an electron tube amplifier structure all the elements of which are small enough so that they are mounted within said case and include at least one voltage amplifier stage and one power amplifier stage each having a cathode heating element and anode circuit elements; a microphone small enough so that it is mounted within said case while exposed to sound propagated through the air surrounding the case; a set of amplifier terminal elements mounted on a wall portion of said case and circuit interconnections within said case for interconnecting said microphone unit and said terminal elements with the elements of said amplifier structure so as to impress the amplified output of said microphone on certain amplifier terminal elements; some of said amplifier terminal elements constituting cathode supply terminals for supplying heating current to said cathode heating elements and some of said amplifier terminal elements constituting anode supply terminals for supplying operating energy to said anode circuit elements; a receiver small enough for inconspicuous wear by the user and cord leads from said certain amplifier terminal elements to said receiver for supplying thereto the amplified output of said microphone; a structurally flat power unit small enough for inconspicuous hidden wear on the body of the user having two compartments and a power supply cord lead unit having cord leads extending from the power unit to the cathode and anode supply terminals of said amplifier unit; a cathode supply cell unit and anode supply cell unit within one compartment of said power supply unit; said cathode supply cell unit being connected through some of said power supply leads to the cathode supply terminals of said amplifier case; a voltage changing arrangement within the other compartment of said power supply unit and connected to said anode supply cell unit; said voltage changing arrangement including a vibratory contactor aggregate and a transformer so designed and correlated and so interconnected between said anode supply cell unit and some of said power supply leads as to cause said contactor to periodically send substantially linearly rising current impulses from said anode supply cell unit through the primary windings of said transformer for inducing a relatively high alternating voltage of substantially rectangular wave shape in the secondary windings of the transformer, and to cause the contactor to rectify the induced alternating voltage and to impress the so rectified voltage on the power supply leads connected to anode supply terminals of said amplifier; and switch means forming part of said amplifier case and including a single movable grip member actuable between a position in which the circuit connection to said anode supply cell unit and the circuit connection to said cathode supply cell unit are broken and a position in which both of said circuit connections are established.

3. In a wearable hearing aid, in combination: a flat amplifier unit having a case small enough for inconspicuous wear on the body of the user; an electron tube amplifier structure all the elements of which are small enough so that they are mounted within said case and include at least one voltage amplifier stage and one power am-

plifier stage each having a cathode heating element and anode circuit elements; a microphone small enough so that it is mounted within said case while exposed to sound propagated through the air surrounding the case; a set of amplifier terminal elements mounted on a wall portion of said case and circuit interconnections within said case for interconnecting said microphone unit and said terminal elements with the elements of said amplifier structure so as to impress the amplified output of said microphone on certain amplifier terminal elements; some of said amplifier terminal elements constituting cathode supply terminals for supplying heating current to said cathode heating elements and some of said amplifier terminal elements constituting anode supply terminals for supplying operating energy to said anode circuit elements; a receiver small enough for inconspicuous wear by the user and cord leads from said certain amplifier terminal elements to said receiver for supplying thereto the amplified output of said microphone; a structurally flat power unit small enough for inconspicuous hidden wear on the body of the user having a power supply cord lead unit having cord leads extending from the power unit to the cathode and anode supply terminals of said amplifier unit; a cathode supply cell unit and anode supply cell unit within said power supply unit; said cathode supply cell unit being connected through some of said power supply leads to the cathode supply terminals of said amplifier case; a voltage changing arrangement within said power supply unit and connected to said anode supply cell unit; said voltage changing arrangement including a vibratory contactor aggregate and a transformer so designed and correlated and so interconnected between said anode supply cell unit and some of said power supply leads as to cause said contactor to periodically send substantially linearly rising current impulses from said anode supply cell unit through the primary windings of said transformer for inducing a relatively high alternating voltage of substantially rectangular wave shape in the secondary windings of the transformer, and to cause the contactor to rectify the induced alternating voltage and to impress the so rectified voltage on the power supply leads connected to anode supply terminals of said amplifier; and switch means forming part of one of said units and including a single movable grip member actuable between a position in which the circuit connection to said anode supply cell unit and the circuit connection to said cathode supply cell unit are broken and a position in which both of said circuit connections are established.

4. In a wearable hearing aid, in combination: a flat amplifier unit having a case small enough for inconspicuous wear on the body of the user; an electron tube amplifier structure all the elements of which are small enough so that they are mounted within said case and include at least one voltage amplifier stage and one power amplifier stage each having a cathode heating element and anode circuit elements; a microphone small enough so that it is mounted within said case while exposed to sound propagated through the air surrounding the case; a set of amplifier terminal elements mounted on a wall portion of said case and circuit interconnections within said case for interconnecting said microphone unit and said terminal elements with the elements of said amplifier structure so as to impress the amplified output of said microphone on certain amplifier terminal elements; some of said amplifier terminal elements constituting cathode supply terminals for supplying heating current to said cathode heating elements and some of said amplifier terminal elements constituting anode supply terminals for supplying operating energy to said anode circuit elements; a receiver small enough for inconspicuous wear by the user and cord leads from said certain amplifier terminal elements to said receiver for supplying thereto the amplified output of said microphone; a structurally flat power unit small enough for inconspicuous hidden wear on the body of the user having a power supply cord lead unit having cord leads extending from the power unit to the cathode and anode supply terminals of said amplifier unit; a cathode supply cell unit and anode supply cell unit within said power supply unit; said cathode supply cell unit being connected through some of said power supply leads to the cathode supply terminals of said amplifier case; a voltage changing arrangement within said power supply unit and connected to said anode supply cell unit; said voltage changing arrangement including a vibratory contactor aggregate and a transformer so designed and correlated and so interconnected between said anode supply cell unit and some of said power supply leads as to cause said contactor to periodically send substantially linearly rising current impulses from said anode supply cell unit through the primary windings of said transformer for inducing a relatively high alternating voltage of substantially rectangular wave shape in the secondary windings of the transformer, and to cause the contactor to rectify the induced alternating voltage and to impress the so rectified voltage on the power supply leads connected to anode supply terminals of said amplifier; and switch means forming part of said amplifier case and including a single movable grip member actuable between a position in which the circuit connection to said anode supply cell unit and the circuit connection to said cathode supply cell unit are broken and a position in which both of said circuit connections are established.

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