April 15, 1952 G. N. HOWATT 2,593,031

LOUD-SPEAKER

Filed May 1, 1948 2 SHEETS—SHEET 1

Fig. 1.

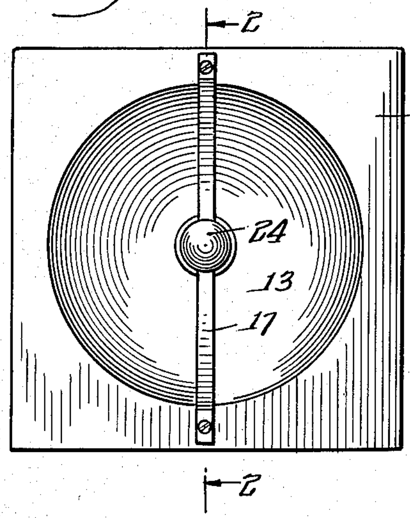

Fig. 2.

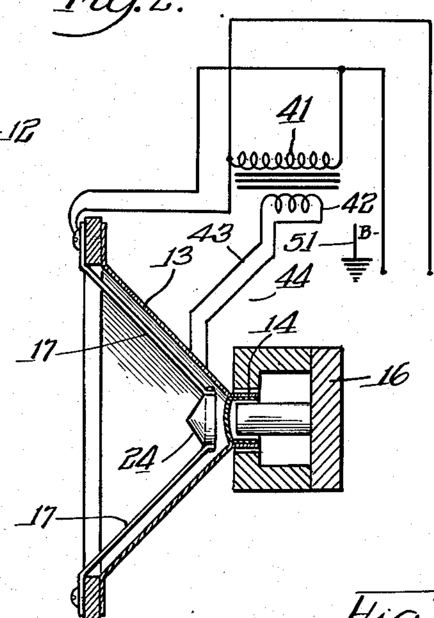

Fig. 3.

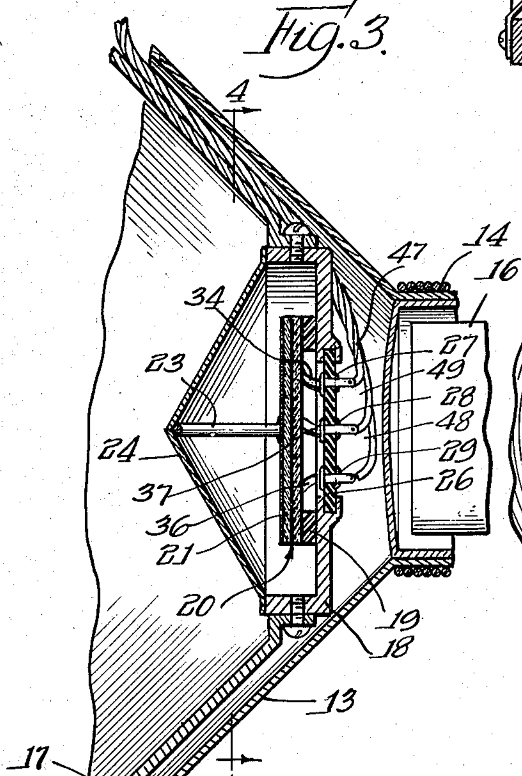

Fig. 4.

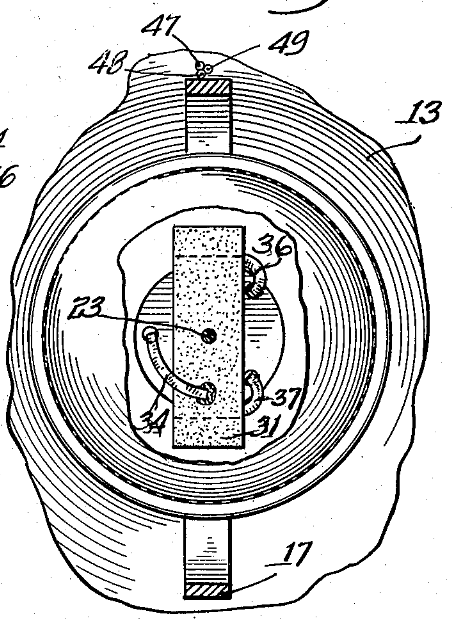

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Fig. 5.

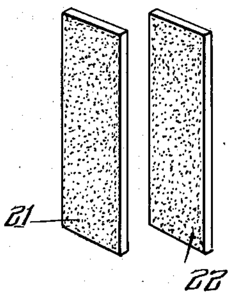


Fig. 6.

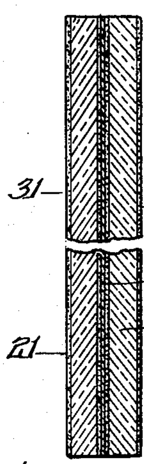


Fig. 7.

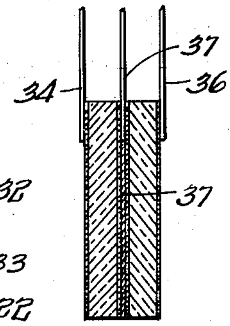


Fig. 8.

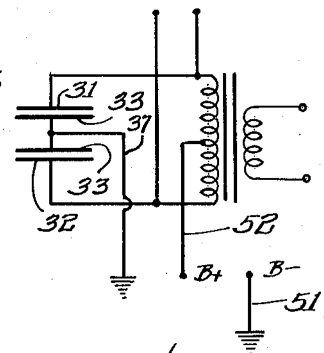


Fig. 9.

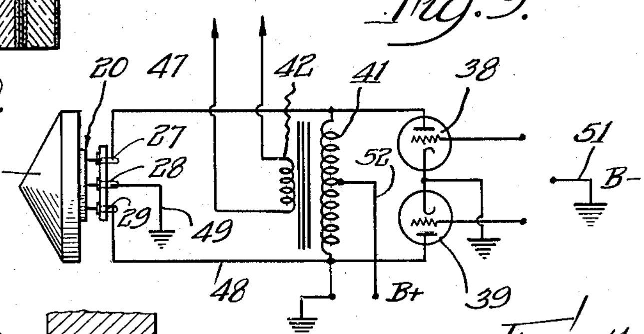


Fig. 10.

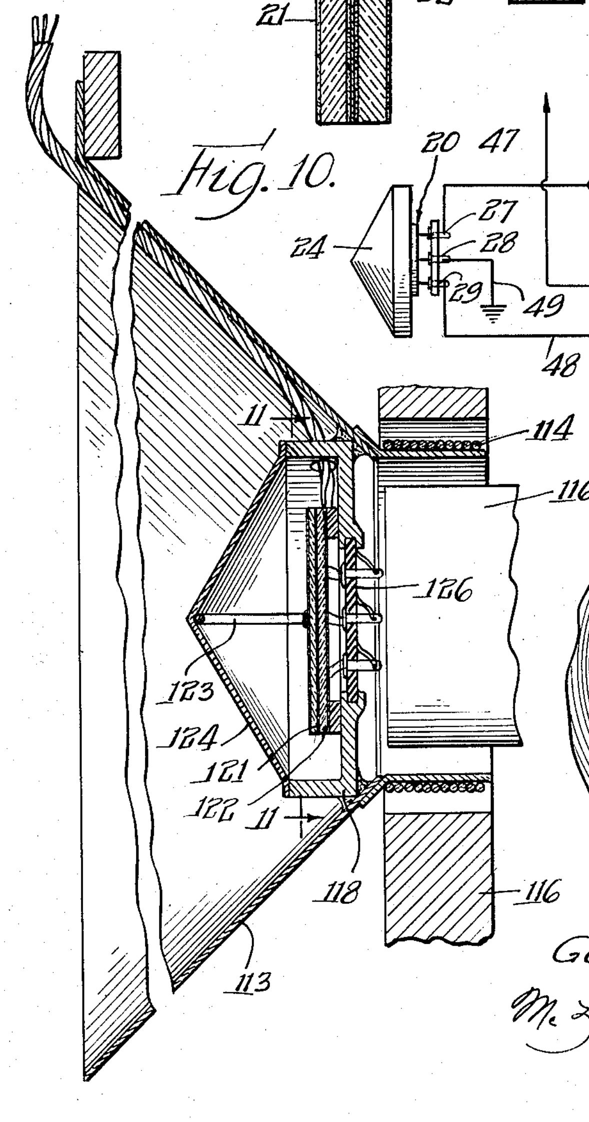
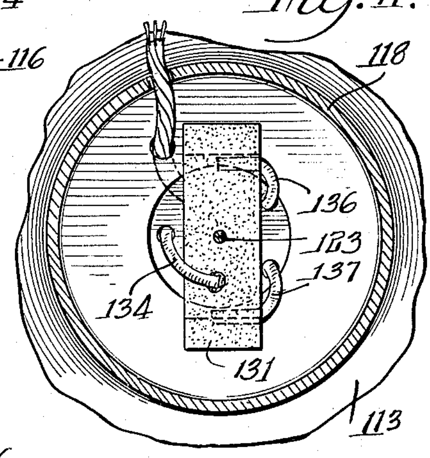


Fig. 11.



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Patented Apr. 15, 1952

2,593,031

UNITED STATES PATENT OFFICE

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LOUD-SPEAKER

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Application May 1, 1948, Serial No. 24,663

3 Claims. (Cl. 179—116)

My invention relates to loud speakers and particularly to the reproduction of high fidelity, higher frequencies in a loud speaker.

Loud speakers have been developed to the point where a uniform response over a moderate frequency band may be obtained in a single diaphragm speaker of the type commonly used in broadcast receivers. The best of such speakers have been capable of operation up to about 9000 cycles, and since the audio frequency spectrum of the usual broadcast band has been well within the range of such speakers, and frequency has not exceeded 5000 cycles, the utility of single cone speakers has been good. In high fidelity broadcasting systems, however, such as in frequency modulation or as would be obtained from high fidelity phonograph records, the frequency range is greatly extended and to reproduce the higher frequencies of the resulting audio frequency spectrum, the loud speaker should have a response up to 15,000 cycles. There have been many suggestions to increase the over-all range of loud speakers such as by the use of more than one speaker mounted coaxially, coplanar and both coaxially and coplanar. The use of two speakers, one to cover the higher frequency band and the other to cover the lower frequency band requires a special cross over network and besides the system so constructed has other drawbacks regardless of how the speakers are mounted.

The object of my invention is the provision of an improved loud speaker system which overcomes the disadvantages of arrangements heretofore suggested.

Another object is the provision of a loud speaker in which two cones are employed but in which a cross over network is not required.

Still another object is to add to a conventional loud speaker having a uniform response over a moderate frequency an additional element or elements which extend the range up to that required in high fidelity transmissions.

A further object is to provide a loud speaker system in which the acoustical response is substantially flat from about 50 cycles to about 15,000 cycles.

In carrying out my invention, I associate with a conventional single diaphragm loud speaker having a uniform response over a moderate frequency band, say from 50 to 9000 cycles, a capacitive type high frequency loud speaker having a uniform response over a range from about 9000 cycles to about 15,000 cycles. The high frequency loud speaker, preferably mounted coaxial and coplanar with the low frequency loud speak-

er, comprises a relatively small cone driven by a piezoelectric ceramic, preferably a polygranular barium titanate ceramic, in which the electrodes of the piezo ceramic are connected to the primary of the output transformer or other portion of the circuit receiving its output from the push-pull audions commonly used in amplifying units, which is so matched to the impedance of the piezoelectric ceramic that no cross over network or other means is required for successful operation. The low frequency loud speaker is connected to a secondary of the output transformer to balance the voltage with the impedance of the voice coil in a manner conventional in the art. The piezoelectric ceramic vibrates in response to so much of the alternating output potential as lies within its frequency range of vibration, and the characteristics of the piezoelectric ceramic are, as previously explained, preferably controlled to provide for vibration within the range of about 9000 cycles to 15,000 cycles. The piezoelectric ceramic is mechanically connected to the high frequency cone to reproduce in the cone the vibrations imparted to the ceramic. In a preferred arrangement, two strips of ceramic are employed being soldered together with a center lead connected to ground. The ceramics will have been charged with opposite polarities so that they complement each other, and the center connection is grounded so that when the minus side of the B power circuit is grounded in the usual manner, there will always be a positive charging potential on the ceramics and even though characteristics may develop, such as raising the temperature of the ceramic above the curie point, which would normally tend to obliterate or reduce the initial charge, the charge is maintained throughout the life of the instrument.

In the drawings, I show details of certain embodiments of the invention wherein:

Fig. 1 is an elevational view of a loud speaker constructed in accordance with my invention;

Fig. 2 is a sectional view taken on the line 2—2 of Fig. 1, and also including a portion of a radio circuit associated with the speaker;

Fig. 3 is an enlarged sectional view showing only a portion of Fig. 2 and illustrating structural features;

Fig. 4 is a fragmentary sectional view taken on the line 4—4 of Fig. 3;

Fig. 5 is a perspective view showing the two ceramics considerably enlarged over those which would have to be employed to drive the small cone;

Fig. 6 is a greatly enlarged longitudinal sectional view showing the electrodes applied to the faces of the ceramic strips;

Fig. 7 is a transverse sectional view on the same scale as Fig. 6 but showing the three leads in position;

Fig. 8 is a partially schematic view of the piezoelectric ceramics and shows the manner in which they are connected into the output circuit of a radio amplifying unit;

Fig. 9 is a partly schematic view of the high frequency loud speaker including cone and piezoelectric ceramics with somewhat more of the circuit than is shown in Fig. 8;

Fig. 10 is an enlarged sectional view similar to Fig. 3 but showing a modified arrangement; and

Fig. 11 is a fragmentary sectional view taken on the line 11—11 of Fig. 10, looking in the direction of the arrows.

Referring now to Figs. 1–9, inclusive, of the drawings, I show a conventional baffle 12 to which the outer rim of a cone 13 is suitably secured in any way conventional in the art. The cone has a voice coil 14 which extends into the annular gap of an electromagnet 16 which may be a permanent magnet of the alnico type or an electromagnet in which charging windings are inductively associated with the center pole piece in a manner conventional in the art. The arrangement of core, voice coil and associated electrical parts, in other words, is entirely conventional and may be employed without change.

Suitably secured to the baffle 12 are a pair of brackets 17 supporting at their inner end an annular mounting ring 18. This mounting ring has a pair of insulating supporting pads 19, which may comprise bakelite or the like, and secured to the pads is a driving unit, indicated generally by the reference character 20, and comprising two piezoelectric ceramics 21 and 22 secured together to form a single assembly as will be described. A driving rod 23 is secured to the ceramic strip 21 and has its outer end connected to the apex of a small cone 24. All of the parts, including the pads 19, driving rod and cone, may be secured together by means of any suitable adhesive.

A terminal block 26 is mounted in a recess at the rear of the ring 18 by merely sliding it into formed channels comprising a part of the mounting ring. The terminal block has three terminals 27, 28 and 29 which are employed to connect the relatively fragile driving unit into the circuit and facilitate making connections thereto.

Looking now first to Figs. 5–7, inclusive, where the larger scale employed facilitates the showing, the ceramic strips 21 and 22 have external electrodes 31 and 32 and a common center electrode 33 which functions to bind them together to form a single unit. Leads 34 and 36 are connected to the electrodes 31 and 32, respectively, and a lead 37 lies between the units and is common to them because of its connection to the center bonding conducting layer. The lead 34 is connected to the terminal 27, the lead 37 to the terminal 28 and the lead 32 to the terminal 29.

In Figs. 2, 8 and 9, I show enough of the audio output portion of a conventional reproducer to indicate the manner in which my high frequency addition may be associated therewith. The circuit shows a pair of audio amplifying tubes 38 and 39 having the usual push-pull relation and having their output connected to a primary winding 41 of an output transformer. A secondary winding 42 is connected to terminals 43 and 44 extending in a suitable conventional manner for connection to opposite ends of the voice coil 14 (see Fig. 3). Since the voice coil is of relatively low impedance, the secondary winding 42 is conventionally engineered to have a much smaller number of turns and is otherwise designed to produce the desired response in the speaker. The full primary voltage, however, is impressed upon the piezoelectric ceramics by means of leads 47 and 48 which are connected in the manner particularly shown in Fig. 9 to the terminals 27 and 29, respectively, and thereby to the oppositely positioned electrodes 31 and 32. This arrangement is also schematically shown in Fig. 8. The impedance of the piezoelectric ceramics is, of course, very high and their characteristic is such that when employed in the manner disclosed only the higher electrical frequencies are effective to set them into vibration and, therefore, only the higher sound frequencies are reproduced. Moreover, the relatively very small mass of the ceramics would prevent their vibrating in the lower audio frequency ranges. Details of the design of specific crystals will be explained below.

The center terminal 27 is grounded at 49 as shown particularly in Fig. 9 and I indicate at 51 the conventional grounding of the negative side of the B power supply. The plus B supply is connected at 52 (see Figs. 8 and 9) to the center of the primary 41 of the output transformer so that the full B voltage is always positively impressed on the piezoelectric ceramics in such a manner as to charge them with opposite polarities with the result that their action is in aid rather than opposing. The leads 47, 48 and 49 are brought to the terminals 27, 28 and 29 in any convenient manner, suitably as indicated in Figs. 1 and 2, by running a three-wire cable along one of the supporting brackets 17 where it will be concealed by the usual grill cloth.

Those skilled in the art will understand that the invention may take various forms and may be carried out in many specific ways. In accordance with one example, the piezoelectric ceramic comprises a substantially pure barium titanate and two flat pieces corresponding to the members 21 and 22 were prepared .020″ thick by ¾″ long by ¼″ wide. These pieces were first painted with a silver fritted paint and baked in an oven for a period of 20 minutes and then removed and allowed to cool. This provided a surface for application of electrodes. One surface of each piece was then tinned with solder and the two tinned surfaces placed together to form a common interface. The resulting composite piece measured .045″ in thickness, .050″ of the total thickness being represented by the soldered layer. The three leads made of brass .010″ thick by .050″ wide were then soldered to the composite element and these comprise the three leads 34, 36 and 37. One lead was soldered to the interface by heating the composite piece sufficiently to soften the solder and then lifting the top piece sufficiently to enable one to place the flexible brass lead between the two pieces. The other two leads were readily soldered to the previously applied fritted paint portions which also act as electrodes. The resulting composite body with the three leads attached was then cemented to the Bakelite pads 19. Following this same specific example, the diaphragm comprised a spun aluminum alloy body 1.1″ in diameter by .002″

thick and with the cone defining a 130 degree angle. The driving rod was .050″ in diameter and .3″ in length. When the total high frequency unit was assembled it was placed in an oven and baked for two hours at 100 degrees C. in order to thoroughly dry the cemented sections. After baking, the unit was allowed to cool and then mounted and electrical connections made in the manner shown in the drawings. The barium titanate polygranular ceramic strips were then charged by connecting the lead **37** to the positive pole of a charging source and the leads **34** and **36** to the negative pole thereof. The total speaker combination, including the low frequency and high frequency units assembled as shown in Figs. 2 and 3, were then placed in a sound chamber and an extremely high fidelity microphone was placed 1½′ directly in front thereof. A signal of 10 volts was applied to the speaker and the acoustic output plotted. The over-all response of the speaker showed a substantially flat curve with a variation of not appreciably more than plus or minus 5 decibels from 50 to 15,000 cycles. The large speaker alone had a flat accoustical response up to about 9000 cycles and the high frequency speaker complemented the low frequency speaker to produce a resultant flat response up to approximately 15,000 cycles. Functional testing showed that high fidelity records could be played having a range of frequencies from the very lowest, of the order of 50 cycles, up to about 15,000 cycles and there was no detectable cancelling out, blasting, or other acoustical aberration throughout the entire series of tests.

In the form of the invention shown in Figs. 10 and 11, the mounting ring **118** is mounted directly into the base of the low frequency cone **113**. In all other respects, the high frequency unit was substantially the same as shown in the main embodiment. In this form of the invention, the same circuits can be employed, the only difference being that the high frequency speaker moves as a unit with the low frequency cone and in a very real sense the speakers are coaxial and coplanar. This form of support is made possible by the extremely light weight of the cone itself and its driving mechanism. I shall not describe the details of this form of the invention but the corresponding parts have the same numerals as in the main embodiment with, however, the prefix "**1**" to indicate modification.

What I claim as new and desire to protect by Letters Patent of the United States is:

1. In a loud speaker, a piezoelectric element including two flat titanate ceramic members secured together face to face and having a common electrode therebetween and each having an outer uncommon electrode, means for supporting the element at its extremities, a speaker cone supported at its extremities, a driving rod secured to the element intermediate its ends and having driving relation with the apex of the speaker cone, signal leads secured to the uncommon electrodes for direct coupling to an amplifier, and a signal lead secured to the common electrode for connection to ground to maintain the uncommon electrodes positive with respect to the common electrode.

2. The combination in a reproducing system of a relatively large diameter low frequency cone speaker having a voice coil, a relatively small diameter high frequency cone speaker having a piezoelectric element including two flat titanate ceramic members secured together face to face and having a common electrode therebetween and each having an outer uncommon electrode, means for supporting the element at its extremities, a speaker cone supported at its extremities and a driving rod secured to the element intermediate its ends and having driving relation with the apex of the speaker cone, a transformer having a secondary and a center tapped primary, the ends of the transformer primary being connected to the output of an amplifier and the center tap thereof to a source of plus potential, electrical connections between the voice coil and the transformer secondary, signal leads connecting the uncommon electrodes to the ends of the transformer primary, and a signal lead connecting the common electrode to ground to maintain the uncommon electrodes positive with respect to the common electrode.

3. The combination in a reproducing system of a relatively large diameter low frequency cone speaker having a voice coil in series with the secondary of an output transformer, and a relatively small diameter high frequency cone speaker having driving means actuated by the primary voltage of the output transformer, said driving means comprising two titanate ceramic bodies secured together to form a common electrode and each having an outer uncommon electrode, signal leads connected to said uncommon electrodes for attachment to the primary of the said output transformer, a lead from said common electrode connected to ground, and a driving rod secured to said ceramic bodies intermediate their extremities and to said small diameter speaker for driving the same at high frequencies, whereby the reproducing system comprising the two cones may be made to have a generally flat acoustical response between about 50 and about 15,000 cycles.

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