June 10, 1969 W. J. ASHWORTH 3,449,531

ELECTRO-MECHANICAL TRANSDUCER

Filed Jan. 9, 1968 Sheet 1 of 2

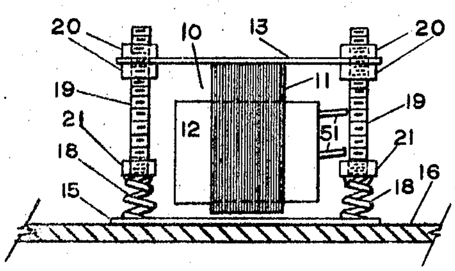

FIG. 1

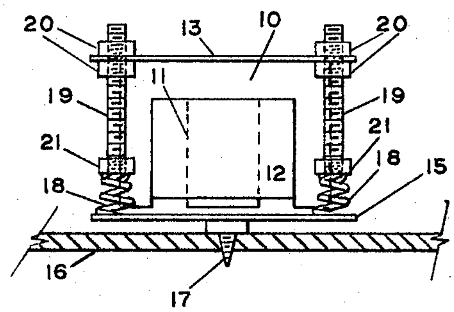

FIG. 2

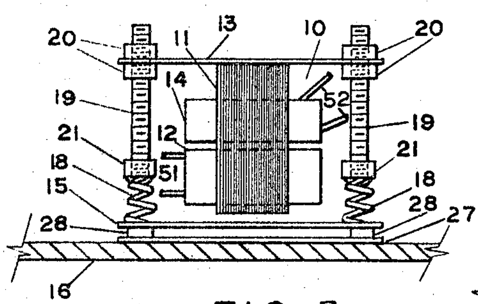

FIG. 3

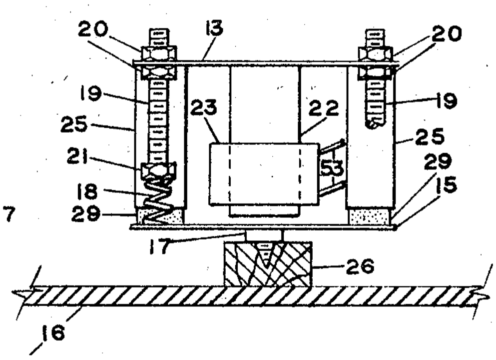

FIG. 4

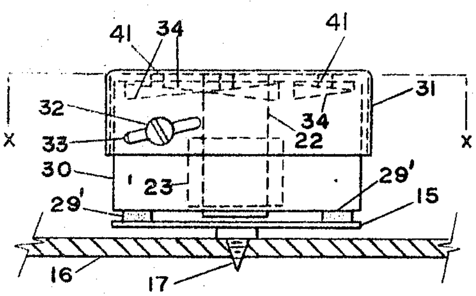

FIG. 5

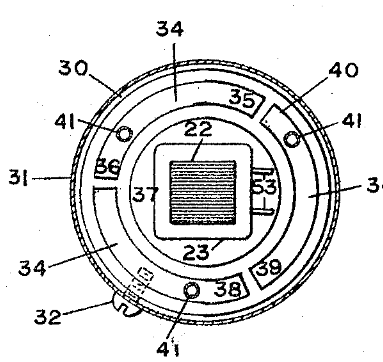

FIG. 6

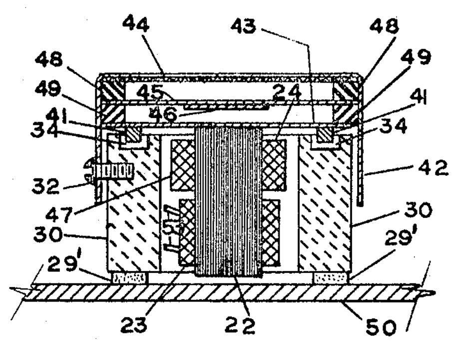

FIG. 7

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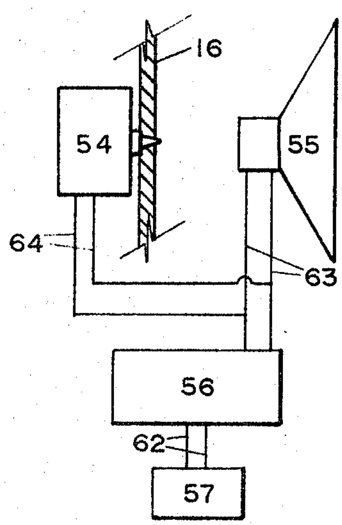

FIG. 8

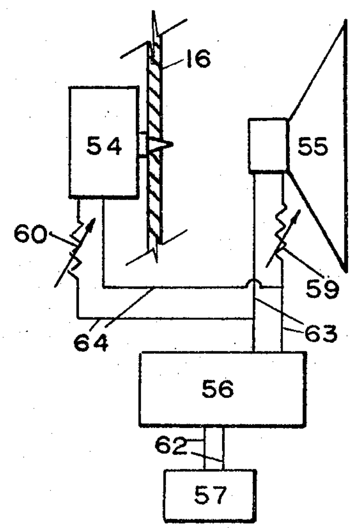

FIG. 9

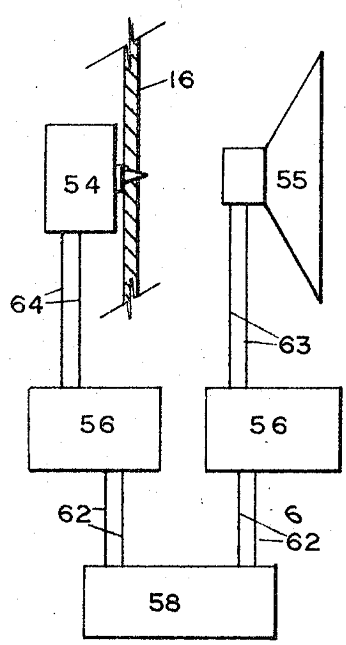

FIG. 10

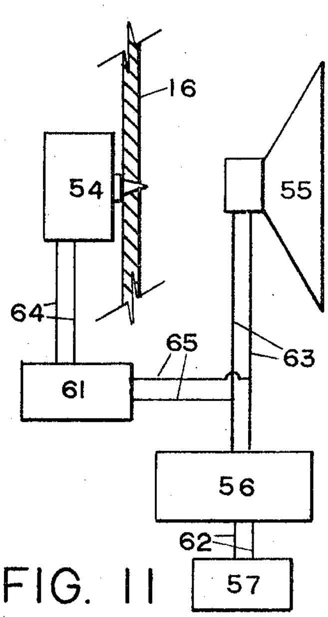

FIG. 11

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3,449,531
ELECTRO-MECHANICAL TRANSDUCER

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Filed Jan. 9, 1968, Ser. No. 696,632
Int. Cl. H04r 7/02
U.S. Cl. 179—115 9 Claims

ABSTRACT OF THE DISCLOSURE

A sound system using a transducer or sound reproducer, having a radiating flexible diaphragm which is attached to a sounding board, for example, walls, doors, car body, etc., causing the sounding board to radiate sound. The electromagnet driving member is resiliently attached to the armature so that the armature and driving members are capable of relative, interacting motion and are thereby capable of good low frequency response as well as a good mid range and high frequency response. The resilient mounting can be accomplished by either springs or resilient pads. Besides sound reproduction, other uses for the sound reproducer are available.

Background of invention

This application is a continuation in part of my copending application, Ser. No. 541,209, filed April 8, 1966 and entitled "Combination Momentum and Inertia Sound Reproducer," now abandoned.

The present invention relates to a magnetically activated transducer, useful particularly in the production of sound and is particularly designed as a transducer unit to be attached to a sound radiating source or sounding board such as a wall, door, or car body, for example.

Heretofore, other electrical sound reproducing devices of the same general type as that described above, have been proposed, for example, that shown in my prior U.S. Patent 3,178,512, issued Apr. 13, 1965, and my U.S. Patent 3,334,195, issued Aug. 1, 1967 but will have had response of only moderate fidelity.

Summary of invention

The present invention solves the low frequency response problem by a unique resilient suspension system whereby the electromagnet driving member and the armature member are capable of relative, interacting motion and permit mutual power transfer between the two. Many refinements and improvements utilizing the unique transducer of the present invention have been devised and are disclosed and claimed below.

Other objects and advantages of the invention will be apparent from the following description taken in conjunction with the accompanying drawings.

Description of the drawings

FIG. 1 is an end elevation view of one embodiment of the present invention.

FIG. 2 is a side elevation view of another embodiment of the present invention.

FIG. 3 is a front elevation of a further embodiment of the present invention.

FIG. 4 is an elevation view of a still further embodiment of the present invention.

FIG. 5 is an elevation view showing an alternate construction of the present invention.

FIG. 6 is a sectional view taken along line *x—x* of FIG. 5.

FIG. 7 is an elevation view of the present invention showing a further alternate construction.

FIG. 8 shows a method of using the present invention in combination with a loudspeaker.

FIG. 9 shows another method of using the present invention in combination with a loudspeaker.

FIG. 10 shows a further method of using the present invention in combination with a loudspeaker.

FIG. 11 shows a still further method of using the present invention in combination with a loudspeaker.

Description of the preferred embodiments

An electromagnet **10** is mounted on the lower side of upper plate **13**, substantially centered with plate **13** and comprises a laminated E shaped frame or core **11** having three equally spaced arms or poles and on the center arm or pole **11** of which is mounted an electrical winding, comprising a coil **12**, whereby the electromagnet may be energized when the coil leads **51** are connected to a signal source.

The diaphragm **15** is non-rigidly or flexibly attached to the upper plate **13** in the following manner. The four screws **19** extend through four equally spaced apertures in the upper plate **13** parallel with the legs of the E frame core **11** and the lower ends of the screws **19** are connected to the upper ends of four coiled spring **18** made of brass. The opposite ends of the four brass springs **18** are firmly connected to the upper face of the diaphragm **15**. As shown, the four screws **19** are longitudinally adjustable in the four apertures of plate **13** by means of locknuts **20** threaded onto the screws **19** one on each side of the upper plate **13**.

The function of the adjustable screws **19** are to adjust the spacing between the diaphragm **15** and the pole pieces of the electromagnet. This spacing is critical for optimum performance. The closer the armature is positioned to the electromagnet pole pieces the greater is the efficiency of operation. However, if the armature spacing is too close to the electromagnet pole pieces, metal to metal contact between the armature and the pole pieces will result.

On the other hand, if the armature is spaced too far away from the electromagnet pole pieces, the efficiency of the sound reproduced will be considerably lowered. It is extremely difficult to maintain this optimum spacing under production conditions. A number of problems complicates the task of maintaining the critical spacing between the electromagnet pole pieces and the armature. If a production parts should slightly vary, the spacing would be incorrect. Tension in various parts could vary and this would require a different spacing between the armature and the electromagnet pole pieces. To overcome the problem of maintaining this critical spacing the system of allowing the diaphragm **15** to be adjusted in or out with the locknuts and the screws was devised. As shown above, the screws **19** are rigidly fastened to brass springs **18** with nuts **21** and are in turn welded to the diaphragm **15**. They are supported by the upper plate **13** and held rigidly in place with locknuts **20**. Diaphragm **15** is pulled toward core **11** by the pull of the electromagnet and is held in a spaced relationship with the electromagnet core **11** by springs **18**. This spaced apart relationship can be adjusted in or out by adjusting locknuts **20** until the optimum spacing between the diaphragm **15** and the electromagnet core **11** is obtained. This eliminates the necessity of attempting to maintain very close fixed tolerances in production. This adjustment is especially advantageous to the present invention because of the relatively long movement between the diaphragm **15** and the electromagnet at certain operating frequencies. When the diaphragm **15** of the transducer embodying the present invention is solidly attached to a sounding board **16** such as a door, wall, ceiling, or other object and an electrical signal is fed into lead wires **51** of the electromagnet the transducer will cause the sounding board **16** to vibrate and radiate sound.

At this point it will be realized that as the electromagnet is activated by a variable electrical current passing through the coil 12, the pole 11 will become variably magnetized and so effect a variable magnetic attraction on the diaphragm 15 thereby imparting vibrations to the sound board 16 onto which the diaphragm 15 is attached.

The brass springs 18 also serve as a resilient restoring means for the normal inactive position of the diaphragm 15 as well as serving as a connector for the spacing means between diaphragm 15 and the electromagnet poles.

An alternate construction of the present invention is shown in FIG. 3. The difference in this construction and the construction in FIG. 1 is in the spacing allowed between the diaphragm 15 and the sounding board 16. The diaphragm 15 and mounting plate 27 are held in a spaced apart relationship by the four equally spaced spacers at the outer edge of the diaphragm 15. When these two plates are fastened together and spaced apart by the spacers 28 they become the dual diaphragm armature assembly. This dual diaphragm armature assembly is connected to the upper plate 13 in the same way and by the same means as the diaphragm 15 in FIG. 1.

A modification of the alternate construction shown in FIG. 3 is shown in FIG. 2 and accomplishes the same result as the dual diaphragm armature assembly as shown in FIG. 3. As shown, an attaching screw 17 is centrally welded to the lower diaphragm 15. Screw 17 serves as an attaching means for solidly attaching the transducer to a sounding board. The head of screw 17 acts as a spacer to hold diaphragm 15 in a spaced relation with sounding board 16.

Due to the weight and inertia of the magnetic core, the coil 12 and the mounting hardware, and because of the flexible resilient mounting means 18, enough weight is present to cause the electromagnet portion of the transducer to remain relatively stable and free from oscillations at operating frequencies above approximately 150 cycles per second. When operating above 150 cycles through approximately 2000 cycles per second, the diaphragm 15 oscillates on its resilient mounting, driving the sounding board structure it is attached to, causing sounding board primary radiating element 16 to vibrate and radiate sound. At operating frequencies below approximately 150 cycles per second, inertia no longer holds the mass of the electromagnet structure in a fixed position and at these low frequencies the electromagnet is free to oscillate at a large amplitude with the relatively rigid or relatively heavy sounding board 16 being a restraining medium. Because of this restraining action these intense oscillations of the electromagnet interact with the diaphragm 15 and are transferred to the sounding board 16. These intense oscillations are allowed because no restraining attachments are connected with the electromagnet assembly 10 other than diaphragm 15 through the flexible mounting 18. The nearer the frequency of the activating electrical signal approaches the natural mechanical low resonant frequency of the transducer mass, the more intense the vibrations become. It is because of these intense vibrations that the momentum of the oscillating transducer mass will transfer enough driving force to the sound radiator 16 as to cause the sound radiator to reproduce good quality bass tones. In the past it has been attempted to cause large heavy surfaces to radiate sound like the described sounding board radiating surface but to obtain any degree of bass response, extremely expensive and large equipment was utilized but with little success because of the natural resistance of a surface to radiate sound with a lower tonal response than its own natural resonant frequency. The present invention has solved this problem by causing extremely intense vibrations to be imparted to the sound radiating surface 16 in the lower frequency ranges.

In order to reproduce good high frequency tones the constructions shown in FIG. 2 and 3 are utilized. At operating frequencies above approximately 2000 cycles, the sounding board 16 has difficulty in reproducing these frequencies. At these frequencies, diaphragm 15, when mounted in a spaced relation with sounding board 16 still remains active and continues to radiate a high level of sound to approximately 8000 cycles. The normal spacing between the diaphragm 15 and sounding board 16 used in the present invention was approximately 1/16 inch although this spacing is not critical.

As can be seen from the above description, three different functions can be performed by the present invention, the first being to reproduce the mid range frequencies by one means, the second being to reproduce the low frequencies by a second means, the third being to reproduce the high frequencies by a third means. These three means are embodied together in the structure of the present invention.

The present invention will operate either as a low impedance device or as a high impedance device. When used as a high impedance device, the constant D.C. currant present in the activating signal is used to produce a biasing magnetic field. The coil lead wires 51 are connected directly to the plate of an audio amplifier output tube and B+. Such a circuit is not described in this disclosure because it is well known to the art. A constant D.C. currant will flow through coil 12, setting up a constant magnetic field around E frame core. This will in turn pull the diaphragm 15 toward the electromagnet, causing tension in springs 18. When a signal is applied to the output tube of the amplifier, this signal will be superimposed on the direct current that is normally flowing. The varying intensity of the signal will cause the transducer to function as previously described. The magnetic bias is necessary to the proper operation of the transducer. This magnetic bias attracts the diaphragm to the electromagnet. The support screws 19 and springs 18 serve as resilient adjustable spacing means to push the diaphragm away from the electromagnet to provide for the proper air gap between the electromagnet and the diaphragm 15.

In the transducer embodiments, the screws 19 are adjusted to provide a gap of approximately 1/16 inch between the electromagnet pole pieces and the armature assembly.

The diaphragm 15 is preferably a disc made of No. 24 gauge M19 electrical steel, two inches in diameter. The upper plate 13 is a disc made of No. 20 guage soft iron, two inches in diameter. Each of the above disclosed embodiments of the present invention comprises core of an electromagnet made from standard ½ inch 29 guage M19 electrical steel E lamination 11 stacked ½ inch high. A high impedance coil wound with 4000 turns of No. 38 magnet wire may be used or a low impedance coil of 200 turns of No. 25 wire may be used. Coiled springs 18 are made of 3 turns of .051 diameter spring brass wire wound in a 5/16 inch outside diameter coil ½ inch long.

When it is desired to operate the present invention connected to a step down audio output transformer or to a transistor amplifier where no constant DC current flow will be present, it is necessary to provide the magnetic bias with a permanent magnet added to the electromagnet structure, for example, as in the embodiments shown in FIG. 4 and 5.

It should also be pointed out that the number of turns of wire required for coil 12 will vary for the different impedance ratings of the various kinds of driving equipment the transducer might be coupled to. For example, 200 turns of No. 25 wire wound on a ½ inch core of M19 electrical steel laminations will have an inductive impedance of approximately 8 ohms at 400 cycles. For high impedance operation, 4000 turns of No. 38 wire wound on a ½ inch core of M19 laminations will have an inductive impedance of approximately 5000 ohms at 400 cycles.

Another embodiment of the persent invention is shown in FIG. 3. Where a high impedance primary winding 12 and a low impedance secondary winding 14 is wound on the core 11. The secondary winding can be used to connect directly to a conventional tweeter dynamic loudspeaker as described and claimed in my Patent No.

3,178,512. Coil **12** shown in FIGS. 1, 2 and 3 can be either a high or a low impedance winding. If a low impedance winding is used, a permanent magnet must be disposed in the magnetic circuit of the electromagnet as described and claimed in my Patent No. 3,358,084.

Different objects and surfaces will reproduce different qualities of sound. The thinner and lighter the material to which the sound reproducer is mounted, the greater will be the volume of radiated sound for a given amount of a signal power. A hollow core door covered with ⅛ inch plywood is easier to drive and requires less driving power than a panel of ⅜ inch sheetrock, therefore, the hollow core door will give louder sound than the sheetrock if the same amount of power is applied to the sound reproducer. The same will be true for ¼ inch plywood paneling and ¾ inch knotty pine paneling. The lighter and thinner ¼ inch plywood will produce a greater volume of sound with the same amount of power applied to the sound reproducer than will the ¾ inch knotty pine paneling.

The sound radiating material to which the sound reproducer is fastened will govern the sound quality obtainable. The sound reproducer will operate well, however, with most materials except concrete and masonry. The sound reproducer can be attached to the sounding board with the screw **17** in the center of the diaphragm **15** as shown in FIG. 2. The diaphragm **15**, FIG. 1, or attaching plate **27** of FIG. 3, may be cemented directly to the sounding board with a suitable cement. A spacing will exist between the diaphragm **15** and the object the sound reproducer is fastened to when the screw **17** is used as the attaching means as shown in FIG. 2. A head on the attaching screw may provide for this spacing.

Another embodiment of the present invention illustrated by FIG. 4 shows a low impedance winding **23** wound on core **22**. Two permanent magnets **25** are secured to the upper plate **13** with, for example, epoxy cement. The magnets are magnetized longitudinally and are mounted so that the north poles of the magnets are positioned in the same direction and magnetically bias the electromagnet core **22** and diaphragm **15**. The diaphragm **15** is nonrigidly or flexibly attached to the upper plate **13**. Additional resilient support means may be used by securing sponge rubber pads **29** between the ends of the magnets **25** and the diaphragm **15**. These sponge rubber pads **29** dampen the intense oscillation of the transducer when the input signal to the transducer coincides with the mechanical resonant frequency of the transducer. The sponge rubber resilient pads **29** may be optional in this embodiment of the present invention.

Core **22** is made from 29 gauge M19 electrical steel ½ inch wide and 1$\frac{1}{16}$ inches long and the electromagnet core **22** is suitably mounted to the upper plate **13** as by a suitable cement such as epoxy cement. The permanent magnets **25** are made of sintered oriented barium ferrite and are 1 inch long, ⅝ inch wide and ⅜ inch thick.

Another form of the present invention is shown in FIGS. 5, 6 and 7 wherein a core **22** is centrally bonded to an iron cover plate or cap **31**. A winding **23** is wound on the core **22**. A ring magnet **30** is bounded with a suitable cement to the inner side of the cover plate **31** which fits over the electromagnet core **22** and coil **23**.

A resilient foam rubber ring cushion **29'**, $\frac{3}{16}$ inch thick, is cemented on the lower end of ring magnet **30** and diaphragm **15** is cemented to the cushion **29'**. Contact cement was found to be suitable for cementing the resilient cushion **29'** to the magnet **30** and diaphragm **15**.

For adjusting the air gap between the electromagnet core **30** and the diaphragm **15**, the upper cover plate **31** has three equally spaced runners **41** welded or formed on its underside which ride on slanting face-cam surfaces **34** molded in the top of ring magnet **30**. As shown, the cam surfaces **34** are depressed $\frac{3}{16}$ inch inward at their ends **35, 37,** and **39** and gradually rise to the level of the upper end of magnet **30** at their ends **36, 38,** and **40,** as shown in FIG. 6 which is a view taken on line *x—x* of FIG. 5. When the circular cover plate **31** is placed in position over ring magnet **30** the runners **41** rest on the cam surfaces **34**. As can be seen from FIG. 6, if the cover plate **31** is turned clockwise with magnet **30** remaining stationary, the runners **41** will follow the inward slope of the cam surfaces **34** lowering the cover plate in relation to magnet **30**. Because the electromagnet core **22** is bonded to the cover plate it will also move inward as the cover plate is turned clockwise. On the other hand, if the cover plate is turned in the opposite direction, the electromagnet core **22** will move in an outward direction relative to the magnet **30**.

It will now be apparent that by rotating the cover plate **31**, the air gap between the core **22** and diaphragm can easily be adjusted for the correct spacing. When the proper spacing has been made, the cover plate **31** is then locked in position with screw **32** which extends through the inclined slot **33** in the sidewall of the cover **31** and screws into a threaded hole in magnet **30**.

It was found that by moving the steel cover plate **31** which provides the magnetic flux path between the core **22** and magnet **30**, away from complete solid contact with the magnet **30** did not affect the performance of the transducer.

Ring magnet **30** was made from sintered non-oriented barium ferrite, 1 inch high with an outside diameter of 2 inches and an inside diameter of 1 inch.

Another form of the present invention as shown in FIG. 7, has a basic construction similar to that as described for the construction in FIG. 5. In this form a secondary coil **47** is added, consisting of 1,500 turns of No. 38 wire and wound on the electromagnet core **22**, which drives an electrostatic operated piezeo element **46**. This construction is and claimed in my U.S. Patent 3,358,084. The piezeo element **46** is cemented to the underside of circular diaphragm **45** made of aluminum foil .008 inches thick. Then the piezeo element **46** is activated by the secondary winding **47**, it in turn activates the foil diaphragm **45** producing a high level of sound in the high frequency range. Suitable frequency blocking or crossover networks may be used for selecting the frequency range desired for this tweeter section. Suitable networks are described in my U.S. Patent 3,358,084.

For better clarity, the leads from the secondary winding **47** are not shown in FIG. 7 but they are connected to each side of element **47**.

As shown in FIG. 7, a spacer ring **49** is cemented on an upper circular plate **43** which carries the runners **41** and engages the cam surfaces **34**. The foil diaphragm **45** is cemented to the upper side of the spacer ring **49** and a second spacer ring **48** is cemented to the upper side of foil diaphragm. A 2 inch circular piece of screen wire **44** is then cemented to the upper side of spacer ring **48** and the entire assembly, comprising parts **43, 44, 45, 46, 48,** and **49**, is cemented to the cover **42**. By turning cover **42**, the air gap is adjusted between the core **22** and diaphragm as described for the construction shown in FIG. 5.

The construction shown in FIG. 7 utilizes a magnetizable metal surface as a sounding board. Foam rubber cushions **29** cemented to the lower side of ring magnet **30** are placed in contact with the metal sounding board **50**. The magnetic attraction between the metal surface **50** and ring magnet **30** will now hold the transducer to the surface **50** without any other holding means. This type of construction is especially useful when used as a sound reproducing means for automobiles. The foam rubber pads **29** may be cemented to sounding board **50** when a permanent installation is desired.

A transistor or other type of tiny radio receiver may be built inside the transducer cover. The transducer is then attached to a sounding board and a far better quality of sound can be obtained than can be had with a small loudspeaker, yet the entire mechanism is extremely small.

Another form of my invention is shown in FIGS. 8, 9, 10, and 11. This form is a continuation-in-part of my now copending application, Ser. No. 558,204, filed June 13, 1966 now abandoned.

The transducer **54** of the present invention and a conventional dynamic loudspeaker **55** are used in combination to form a unique sound system. The advantage of such a sound system resides in the fact that when transducer **54** and loudspeaker **55** are driven by the same signal, the sounding board **16** activated by transducer **54** and the paper diaphragm of loudspeaker **55** have a different decap time. For example, when a given tone is fed to transducer **54** and loudspeaker **55** from amplifier **56** and signal source **57**, sounding board **16** and the diaphragm of speaker **55** will be caused to vibrate. When the signal ceases, the vibration decay time of the loudspeaker paper cone will be faster than the decay time of the large sounding board **16**. This gives a very pleasing sound sensation to the listener resembling true reverberation. This reverberation effect gives much more realism and is more pleasant to listen to than systems utilizing the spring type units.

There is considerably less distortion present in the system using the transducer of the present invention than in the reverberation systems using the spring type reverberation units such as described in my U.S. Patent 3,174,-121.

FIG. 8 shows transducer **54** and a loudspeaker **55** in parallel driven by amplifier **56** actuated by a signal source **57** which may be a radio tuner, turntable, or other signal source. Leads **62** connect the signal source with the amplifier and leads **63** and **64** connect the amplifier output with the sound reproducing means **55** and **54** respectively.

FIG. 9 shows transducer **54** and loudspeaker **55** connected in parallel driven by amplifier **56** activated by signal source **57**. Transducer **54** and loudspeaker **55** have a volume control **59** and **60** in their respective lines for controlling the volume of each independently of the other.

FIG. 10 shows transducer **54** and loudspeaker **55** driven by individual amplifiers **56**. This allows for individual control for the transducer **54** and loudspeaker **55**. Amplifiers **56** may be activated by the same signal or each amplifier **56** may be activated by a stereo signal source **58** such as a stereo phonograph record.

FIG. 11 shows loudspeaker **55** driven directly through leads **63** by amplifier **56** with amplifier **56** being activated by signal source **57** through leads **62**. The input of amplifier **61** is connected to the output of amplifier **56** by leads **65** and the output of amplifier **61** is connected to transducer **54** by leads **64**.

It should be understood that the transducer of the present invention requires more driving power to drive a large sounding board than is required to drive a light loudspeaker paper cone. This is the reason means are shown in FIGS. 9, 10 and 11 to regulate the power to each sound reproducing means **54** and **55**. The sound from each reproducing means may be balanced to the exact loudness best suited to the individual listener.

Although several specific embodiments of this invention have been herein shown and described, it will be understood that details of the constructions shown may be altered or omitted without departing from the spirit of the invenion as defined by the following claims.

I claim:

1. An electro-mechanical transducer comprising a driving element including a magnetic core and a coil of wire wound on said core, said core being solidly attached to a mounting plate, an armature of magnetizable material mounted in axially spaced relation with said magnetic core, resilient coupling means connecting said armature element with said mounting plate for permitting relative motion and mutual power transfer in all directions between said driving element and said armature element, magnetic biasing means disposed generally parallel with

said core between said mounting plate and said armture, a sounding board for supporting said transducer, and means rigidly connecting said armature to said sounding board.

2. An electro-mechanical transducer comprising a driving element including a magnetic core and a coil of wire wound on said core, said core being solidly attached to a mounting plate, an armature means of magnetizable material disposed in axially spaced relation with said magnetic core, resilient coupling means connecting said armature means with said mounting plate for permitting relative motion and mutual power transfer in all directions between said core and said armature means, and permanent magnet disposed generally parallel with said core between said mounting plate and said armature means.

3. A transducer element according to claim **1** or **2**, wherein means is provided for mounting the armature on the sounding board in partial spaced relation therewith, whereby the armature may vibrate independently of the sounding board and its attachment thereto for imparting sound into the surrounding area.

4. An electro-mechanical transducer comprising a magnetic driving element and a magnetically driven element, means for resiliently coupling said driven element and said driving element in spaced relation with each other, a sounding board for supporting said transducer, and coupling means extending from the driven element for solidly attaching said driven element in spaced relation with and to a said sounding board, whereby said driven element may vibrate concurrently with and independently of said sounding board.

5. An electro-mechanical transducer for producing sound vibration comprising a magnetic core and an electrical coil wound on said core, said magnetic core being fixedly attached to a mounting plate, a magnetizable armature axially spaced from said magnetic core, spacing means extending generally parallel with said core between said mounting plate and said armature, and means for adjusting the axial spacing between said magnetic core and said armature, said adjusting means comprising axially slanting cam tracks located at the end of said spacing means opposite said armature, said mounting plate having runners disposed to ride on said slanting cam tracks, and said mounting plate being rotatable on said tracks for moving said magnetic core axially toward and away from said aramture.

6. A transducer according to claim **5** wherein said spacing means comprises a permanent magnet.

7. A transducer according to claim **5** or **6** wherein means are provided for holding said totatable mounting plate in a fixed position relative to the armature.

8. An electro-mechanical transducer according to claim **2** or **6** wherein the permanent magnet is a body having an opening extending therethrough from end to end, and said magnetic core extends into the opening of said body from the end thereof remote from the armature.

9. With an electro-mechanical transducer according to any one of claims **1**, **2**, **4**, and **5** the combination of a dynamic speaker electrical coupled with said transducer to a signal source common to both the transducer and dynamic speaker.

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U.S. Cl. X.R.

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