Jan. 15, 1963 P. T. FARNSWORTH III 3,073,899

TRANSDUCING APPARATUS

Filed March 29, 1957

3 Sheets-Sheet 1

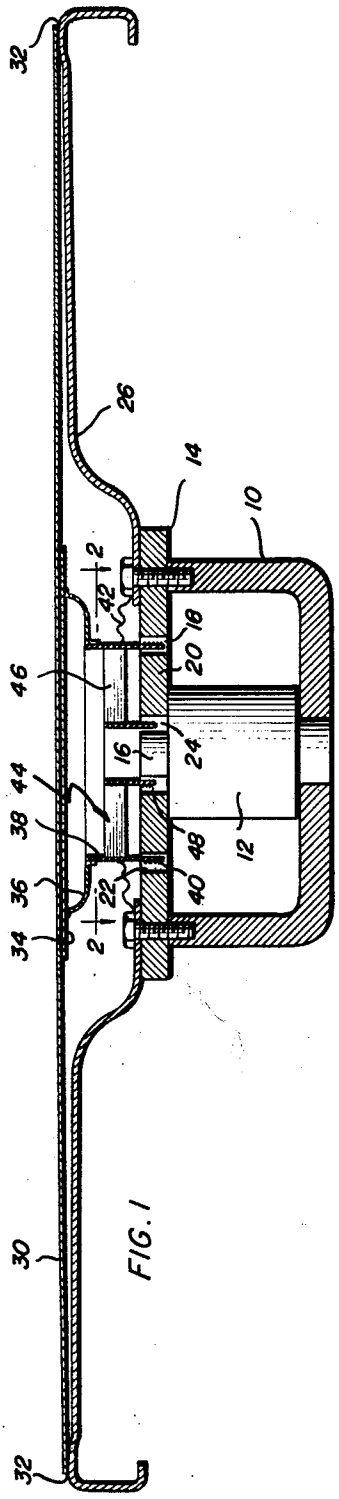


FIG. 1

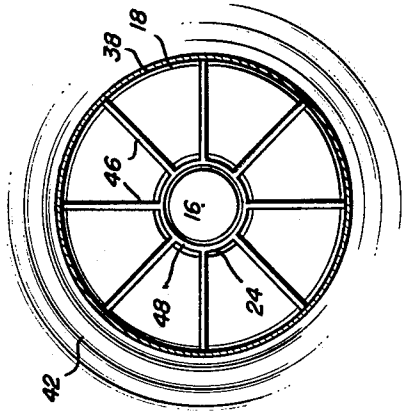


FIG. 2

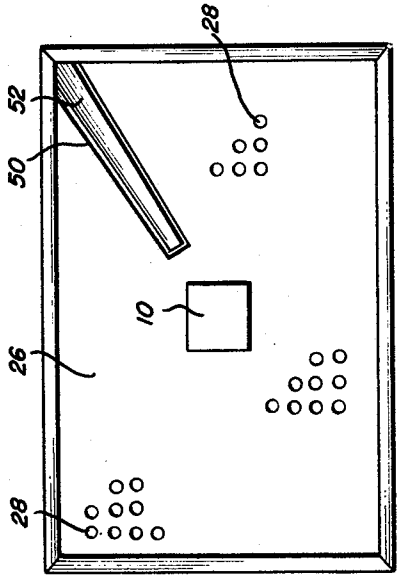


FIG. 3

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3 Sheets-Sheet 2

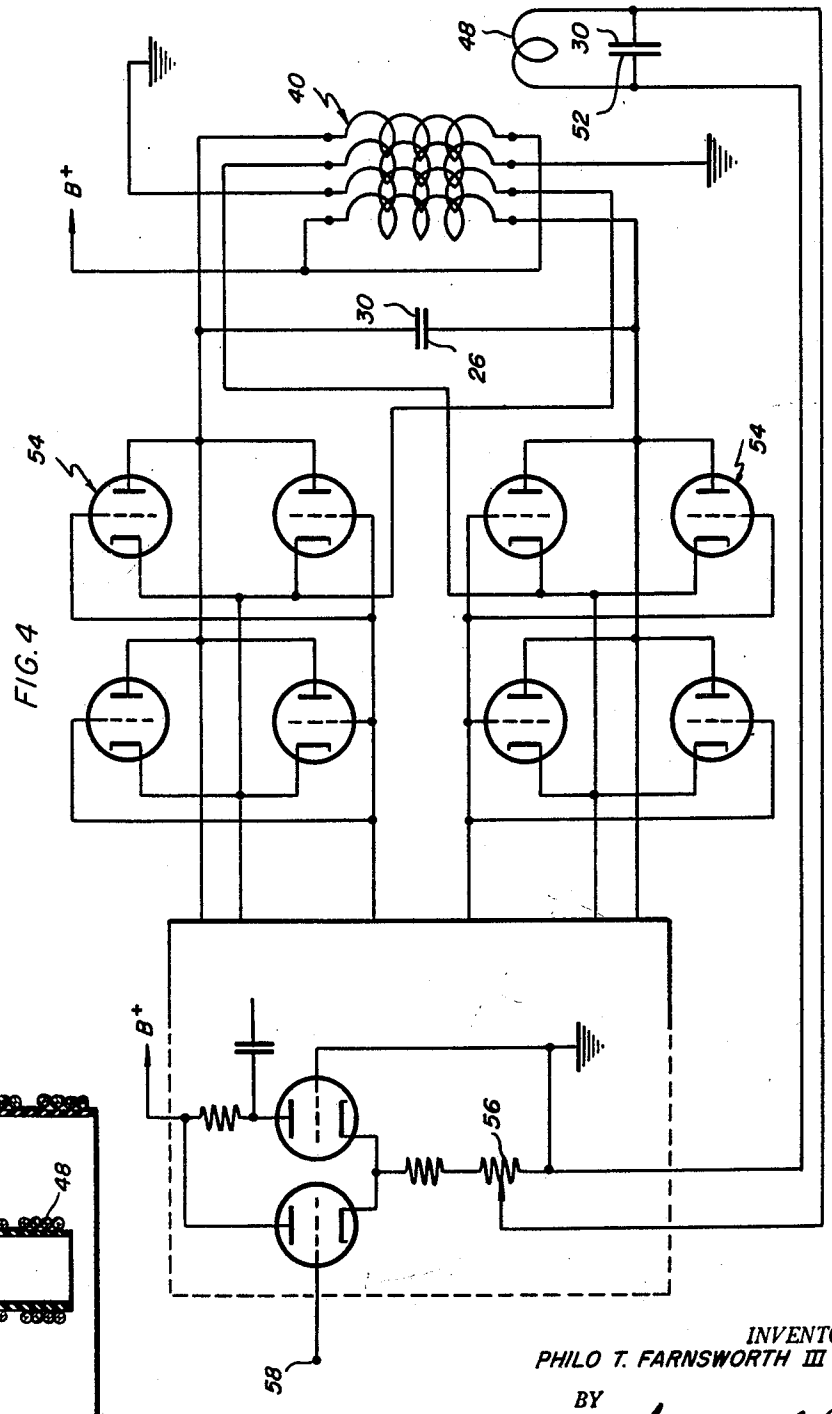


FIG. 4

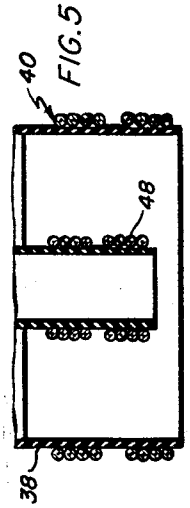


FIG. 5

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Jan. 15, 1963 P. T. FARNSWORTH III 3,073,899

TRANSDUCING APPARATUS

Filed March 29, 1957 3 Sheets-Sheet 3

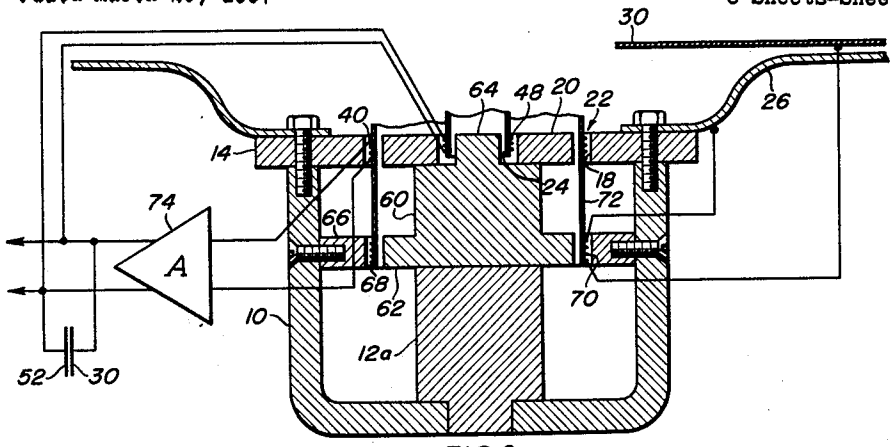


FIG.6

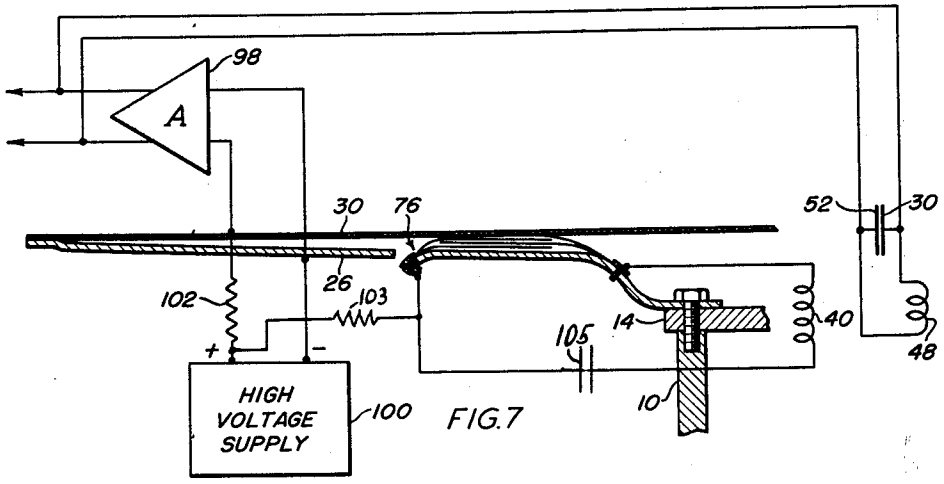


FIG.7

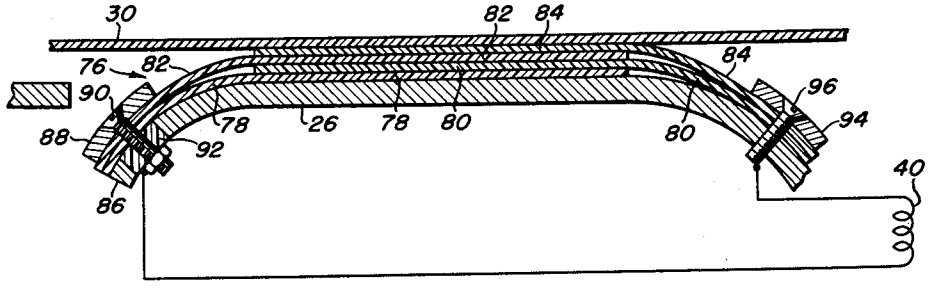


FIG.8

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United States Patent Office

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3,073,899

TRANSDUCING APPARATUS

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Filed Mar. 29, 1957, Ser. No. 649,527
21 Claims. (Cl. 179—1)

The present invention relates to a transducing apparatus and more particularly to a speaker system for reproducing high fidelity sound.

Audio amplifier systems customarily utilize feedback for minimizing distortion in the reproduced sound. Different feedback circuits have been proposed and used conventionally, one configuration deriving the feedback signal from the audio output transformer, and another utilizing an output transformer loop or equipment means from which the signal is obtained. The feedback signal of both of these configurations, however, includes an error signal composed in part of distortion reflected from the speaker voice coil for which there is no simple method or means of compensating.

Desirably, the feedback signal should be representative of the speaker cone or diaphragm vibration, which vibration departs to a greater or lesser extent from the command or true signal due to the inertia of speaker parts, compliance of the cone or diaphragm, loading of the cone or diaphragm by the surrounding air, and the like. By generating a signal representative of the cone or diaphragm vibration, a true error signal or a signal representing the departure of the diaphragm from the command excitation is achieved. Such a signal may be regarded as the electrical equivalent of diaphragm motion, and if the signal is in the form of a voltage, it may be termed a "motional voltage."

Such "motional voltage," useful as feedback for minimizing distortion, is obtained in one prior art device by winding a separate feedback coil of very fine wire over the existing voice coil in a conventional speaker. The voltage induced in this coil by the motion of the voice coil is a true motional voltage at some frequencies, and provides the advantage of including therein non-linearities of the cone suspension in the feedback loop and reducing distortion from this cause.

However, mutual induction between these two coils is a difficulty encountered at the higher frequencies and must be compensated for by the use of balancing circuitry interposed at a point external to the magnetic field of the speaker. Thus, this prior art arrangement cannot provide a true motional voltage for all frequencies without the use of extra networks.

Popularly priced high-fidelity speakers and speaker systems are all limited in the performance thereof by the characteristics of compliance, driver and diaphragm mass, low resonant frequency, gap flux, damping, power handling capabilities, driver efficiency in a multi-driven system, electrical and physical non-linearities, and radiation resistance. It thus becomes highly desirable and essentially necessary in achieving a relatively low-cost, high fidelity speaker and speaker system to optimize each and every one of the foregoing features in a low-cost, simple and efficient structure or system, and as will appear in the following description and related drawings, this optimization is accomplished by means of the structural and functional characteristics of this invention.

It is therefore an object of this invention to provide a high fidelity speaker system which is simple in construction, efficient in operation and inexpensive to produce.

Another object of the invention is to provide a combination magnetically and electrostatically driven vibration element which is servo-stabilized.

Still another object of the invention is to provide a diaphragm which is driven by combination magnetic and

electrostatic means stabilized against distortional vibration.

Yet another object of the invention is to provide for a speaker construction, a flexible planar diaphragm as a vibrating element which is driven by cooperatively associated magnetic and electrostatic motors and which is stabilized against distortional vibration by means of magnetic and electrostatic sensing devices.

Still another object of this invention is to provide an arrangement including a flexible planar diaphragm which is vibrated as a unit or stiff plunger.

A still further object of the invention is to provide in a speaker system a feedback or servo device which generates a voltage corresponding to the motion of the speaker vibrating element.

Still another object of the invention is to provide a speaker system wherein the speaker voice coil is directly coupled to the output tubes of the audio-amplifier.

Other objects will become apparent as the description proceeds.

In the accomplishment of this invention, there is provided a vibrating element driven by two dissimilar motors or drivers which are servo-stabilized by means of two different sensing devices. One of these drivers is magnetic in character while the other is electrostatic. Similarly, one of the sensing devices is magnetic in character and is physically coupled to the magnetic driver, and the other sensing device is electrostatic and in part consists of a functional element of the electrostatic driver. The two sensing devices generate signals which are truly representative of the motion of the vibrating element, and these signals are degeneratively coupled into the amplifier system in any conventional manner for reducing motional departure of the vibrating element from the true or command signal.

To the accomplishment of the above and related objects, the invention may be embodied in the forms illustrated in the accompanying drawings, attention being called to the fact, however, that the drawings are illustrative only, and that specific change may be made in the specific constructions illustrated and described, so long as the scope of the appended claims is not violated.

In the drawings:

FIG. 1 is a cross-sectional illustration of one embodiment of this invention;

FIG. 2 is a sectional view taken substantially on section line 2—2 of FIG. 1;

FIG. 3 is a rear plan view of the construction of FIG. 1;

FIG. 4 is a schematic diagram incorporating the speaker of FIG. 1;

FIG. 5 is an axial sectional view of a voice coil construction which may be used in the speaker;

FIG. 6 is a fragmentary sectional illustration of another embodiment of this invention;

FIG. 7 is a fragmentary illustration of still another embodiment of this invention; and

FIG. 8 is an enlarged sectional illustration of a portion of the structure of FIG. 7.

Referring to the drawings, and more particularly to FIGS. 1, 2 and 3, the speaker therein illustrated comprises a yoke **10**, a permanent magnet-type slug **12** of Alnico V or the like secured thereto, and an annular plate **14** bridging the yoke and slug, this plate **14** being composed of any suitable magnetic material.

The upper end **16** of the slug **12** is reduced in diameter, and the plate **14** is ring-shaped having an inner opening **18**. A second similar ring **20** is cemented or otherwise suitably secured to the slug **12** in coaxially spaced relation with respect to the slug tip **16**. The outer diameter of this ring **20** is somewhat smaller than the diameter of the ring opening **18** thereby providing an annular air

gap 22. The space between the slug tip 16 and the ring 20 provides a second annular air gap 24.

A metallic frame or plate 26 fabricated of sheet metal suitably formed to shape and provided with a plurality of apertures 28 is bolted to the plate 14 and yoke 10 as shown. This frame 26 is rigid and forms one functional portion of the speaker construction, as will become apparent from the succeeding description.

A diaphragm 30 of approximately the same area and shaped as that of backing plate 26 is secured to the peripheral edges 32 of the backing plate. This diaphragm 30 may be composed of any suitable flexible material which is electrically conductive, examples of such material being a fabric sheet or plastic film rendered conductive by a coating or foil of metal which may be applied by the well-known evaporating or sputtering techniques. Other possible methods of rendering the diaphragm 30 conductive will occur as obvious to a person skilled in the art.

As viewed in FIG. 1, the backing plate 26 is progressively spaced farther from the diaphragm 30, moving radially inwardly toward the diaphragm center, the reason for this particular spacing becoming apparent from the following description.

Preferably, the diaphragm 30 is fabricated to varying thickness and density along its radial extent, the thicker portions being disposed in the central region. In the central region 34, the diaphragm is stiffened by means of a suitable reinforcing plate or the like to render it inflexible, and is secured to a grid work of crossed ribs 36 which, in turn, is fixedly secured to a tubular voice coil support 38. This voice coil support 38 projects into the annular air gap 22 and carries on its lower end a voice coil 40.

An annular compliance 42 provides support for the voice coil from the frame or backing-plate 26.

A mounting spider 44 composed of radial ribs 46 is fixedly secured to the internal wall of the voice coil support 38 and carries at its center a feedback coil 48. Thus, the voice coil 40 and feedback coil 48 are coaxially tied together and will move as a unit. As will be noted in FIG. 1, the inner air gap 24 reciprocably receives the voice coil 40.

As seen in FIG. 3, the backing-plate 26 is provided with an elongated slot 50 of suitable width which receives a strip 52 of sheet metal of self-supporting character. The strip 52 is electrically insulated from the backing plate 26 and is spaced from the diaphragm 30 a distance which will become apparent from the following description.

Preferably, this strip 52 is adjustable inwardly or outwardly from the diaphragm 30.

Referring now to FIGS. 4 and 5, like numerals will indicate like parts. A preferred construction for the voice coil 40 consists of a low impedance quadrifilar winding. This winding is fabricated of four side-by-side wires helically wound on the support 38. These four wires thus coiled are mutually inductive and are connected into a typical triode push-pull amplifier circuit as illustrated. It will be noted that the voice coil is conductively connected to the plates and cathodes of the output tubes 54 and that no output ransformer is needed for matching the impedance of these tubes to that of the voice coil. The impedance of the voice coil 40 is matched to that of the output tubes 54, which perferably are of the low impedance, high current type.

With the speaker of FIG. 1 connected in the circuit of FIG. 4, the feedback coil 48 and the sensing condenser composed of the diaphragm 30 and backing strip 52 are connected in parallel with leads extending therefrom to the input tube cathode circuit 56. Any other suitable connection to the input end of the amplifier is possible so long as the phase relation between the feedback signal and the input or command signal is proper. This phase relationship is conventional.

The diaphragm 30 and backing plate 26 may be considered as constituting two plates of an ordinary capacitor. This portion of the speaker will be recognized as being similar to an electrostatic speaker which is excited by charge signals applied thereto. The central portion 34 of the diaphragm is driven by means of the magnetic motor or voice coil 40. Thus, it will be noted that two different or dissimilar motor means, one magnetic and the other electrostatic, are used to drive the diaphragm 30.

In the circuit of FIG. 4, the electrostatic driver 26, 30 is connected in shunt with the voice coil 40.

In operation, the audio signal fed to the input terminal 58 of the amplifier is amplified and fed to the capacitor 26, 30 and the voice coil 40 simultaneously. These two drivers 26, 30 and 40 drive or move the diaphragm 30 in unison as a single unit, as if the diaphragm 30 were inflexible and consisted of a stiff plunger.

For low frequency signals, the motion of the driver 40 is slow enough that the entire diaphragm 30 will move as a unit. However, as the region of higher frequencies is entered, the driver 40 reciprocates at a rate too rapid for the outer peripheral regions of the diaphragm 30 to follow. There thus results a standing wave or rippling in the outer diaphragm regions which produce distortion in the resulting sound. This rippling is prevented, however, by means of the electrostatic driver 26, 30 in combination with the sensing capacitor 30, 52 which senses the ripple and provides a signal which is coupled back into the amplifier and fed to the driver 26, 30 in compensating phase relationship. Thus, the diaphragm is prevented from rippling in the higher range of audio frequencies and is thus caused to move as a unitary plunger in a linear manner.

As mentioned earlier, the diaphragm is constructed of radially varying density or thickness, the reason for this being to dampen the high frequencies and thereby prevent reflection of waves from the diaphragm periphery.

As is well-known, all diaphragms or all vibrating elements of speakers possess a certain amount of mass and inherent motional impedance which prevent them from moving identically with the wave form of the true signal applied to the voice coil. In other words, assuming a sinusoidal wave is applied to the voice coil 40, the diaphragm 30, because of its inherent motional impedance, as well as the inertia of the other speaker parts, will move in some pattern other than a pure sinewave. Since the total diaphragm motion results in identical reciprocatory motion of the feedback coil 48, a feedback signal is generated which is fed back into the input circuits of the amplifier as already explained. This amplified feedback signal will be out of phase with and will thus attenuate the command signal applied to the voice coil 40, and will contain components corresponding identically to the distortional movement of the diaphragm. Since the pure command signal does not contain these distortional components, the amplified feedback signal which is applied to the voice coil 40 will be almost precisely out of phase with the diaphragm distortional movement, thereby appreciably minimizing or completely eliminating it.

This cancellation of distortion is due in part to the fact that there is either no or at most only slight phase shift between the feedback signal of the coil 48 and the command signal applied to the voice coil 40. This lack of phase shift is attributable in part to the fact that both air gaps 22 and 24 are in series in the magnetic flux path of the two rings 14 and 20, and the two coils 40 and 48 move in unison in this flux path.

By reason of the fact that the voice coil 40 is coupled directly to the output tubes 54 of the amplifier and the fact that the feedback voltage from the coil 48 is directly attributable to motion of the diaphragm 30, a true motional voltage, as the feedback voltage, is generated for overcoming distortion and for other reasons. The system provides a minimum of phase shift over the entire frequency spectrum between the feedback and command signals, and the feedback signals, as derived from the feedback coil 48 and sensing capacitor 30, 52, are truly motional volt-

ages. Vibrational distortion in the diaphragm **30** is appreciably reduced and fidelity of sound reproduction is necessarily achieved. The inertia of speaker parts, compliance of the diaphragm, air loading on the diaphragm and the like are automatically mirrored in the feedback voltage, since diaphragm motion is affected by these elements as a part of its total environment. Loading of the diaphragm is therefore no problem, with the result that the need for costly speaker enclosures is eliminated.

While the sensing capacitor **30**, **52** is illustrated as consisting of the strip **52** spaced from the diaphragm **30**, it will be apparent that other constructions such as screw adjusted condenser plates or the like may be used instead whereby the amplitude of the feedback signal may be adjusted to a desired level. Such alternative arrangements, of course, will fall within the scope and spirit of this invention.

Referring to FIG. 6, a modified arrangement of this invention is illustrated wherein like numerals represent like parts. Comparing this FIGURE with FIG. 1, the magnet **12***a* has superposed thereon a slug **60** of magnetic material, this slug having an enlarged diameter portion **62** on its lower end and a reduced diameter portion **64** on its upper end. The air gap **24** is provided between the end **64** and the ring **20** for receiving the feedback coil **48**.

Secured to the inside of the yoke **10** is a ring **66** of magnetic material which is spaced from the slug end **62** as shown. The spacing between this ring **66** and slug end **62** provides a third air gap **68** which reciprocably receives a secondary or driving inductor or coil **70** which is wound on a coil form **72**. The voice coil **40** is also wound on this coil form **72** whereby the vibratory motion generated by the interaction of the voice coil and the magnetic field will serve to produce like motion of the driving coil **70**. Flux lines from the magnet **12***a* in addition to passing through the air gaps **22** and **24** also traverse the air gap **68**, whereupon motion of the coil **70** serves to produce a voltage which is useful in driving the electrostatic motor **26**, **30**. As seen in FIG. 6, the coil **70** is connected directly to the frame **26** and the diaphragm **30**.

The amplifier **74** may be conventional in the respect that it provides an output circuit having an impedance which matches that of the voice coil **40**. Since the electrostatic driver **26**, **30** is driven directly by the coil **70**, there is no connection between the driver **26**, **30** and the amplifier **74**. The feedback coil **48** as well as the sensing capacitor **30**, **52** are coupled back into the input circuit of the amplifier **74** the same as in the preceding embodiment.

This particular construction may be preferred in some instances over that illustrated in FIGS. 1 and 4, since actuation of the driver **26**, **30** from the coil **70** permits achieving an impedance match which is more favorable than that attainable in the embodiment of FIGS. 1 and 4. This being true, the efficiency and performance of the electrostatic driver **26**, **30** is reflected back into the load on the voice coil **40** which, in turn, is matched to the output circuit of the amplifier **74**. Since the diaphragm **30** is directly connected to the coil form **72**, all three of the coils **40**, **48** and **70** will move in unison therewith.

Referring to FIG. 7, an alternative embodiment to that of FIG. 6 is shown wherein an electrostatic driver, indicated generally by the reference numeral **76**, is used to energize the voice coil **40**. This driver **76**, which is shown in enlarged detail in FIG. 8, is composed of a plurality of laminations or interleaved conductive plates or surfaces which are insulated from each other. Alternate ones of these plates or surfaces are connected together at the opposite ends, thereby providing a capacitor. The capacitor plates or elements in the illustrated embodiment are composed of suitable plastic films or membranes **78**, **80**, **82** and **84** having on the upper surfaces thereof, respectively, either a metallic foil, such as aluminum, or a conductive coating of any of the usual types. These films **78**, **80**, **82** and **84** extend around the inner periphery of the frame **26** in a closed loop, the particular shape of this loop depending upon design requirements. The backing plate **26** is lanced in a number of places to provide flanges or mounting lugs **86** which are bent downwardly. The conductive surfaces on the two tapes **78** and **82** are connected together by means of a suitable clamp **88** and screw **90**, the latter passing through a feed-through insulator **92** which is secured in the mounting lug **86**.

The conductive surfaces on the other two elements **80** and **84** are similarly connected together by means of a suitable clamp **94** and screw **96**, which may be grounded directly to the frame **26**.

The resulting electrostatic driver **76** is sandwiched between the frame **26** and the diaphragm **30**, so that vibration of the diaphragm **30** will result in corresponding movement of the respective elements **78**, **80**, **82** and **84**.

In making circuit connections, the voice coil **40** is connected between the two screws **90** and **96** as shown. The amplifier **98** (FIG. 7) is coupled directly to the diaphragm **30** and frame **26** for driving the same, the impedance of the amplifier circuit matching that of the diaphragm and frame. A polarizing voltage is supplied by the power supply **100**, which is also coupled directly to the frame and diaphragm through a suitable isolating resistor **102**. A second isolating resistor **103** connects between the power supply **100** and the screw terminal **90**. A blocking condenser **105** is connected in series with the voice coil **40** as shown.

In operation, the amplifier **98** actuates the electrostatic driver **26**, **30** directly. As a result of vibration produced in the diaphragm **30**, the auxiliary driver **76** is similarly vibrated, thereby producing a signal voltage which is coupled directly to the voice coil **40**. The voice coil **40** in turn imparts its vibratory motion resulting from the energizing signal voltage to the diaphragm **30**.

It will understood as obvious that this embodiment of FIGS. 7 and 8 is identical in all respects to the structure of FIG. 1, with the exception that the voice coil **40** is driven by the auxiliary driver **76** instead of directly from the amplifier of FIG. 4.

What is claimed is:

1. Apparatus of the character described comprising vibrating means, first motor means for driving said vibrating means, second motor means for driving said vibrating means, said first motor means being magnetic and said second motor means being capacitive, first sensing means operatively coupled to said first motor means for generating a first distortion-compensating signal, and second sensing means for generating a second distortion-compensating signal, said second sensing means including means for sensing motion of said vibrating means throughout substantially the entire vibrating extent thereof and means utilizing both distortion-compensating signals for reducing to a minimum motional distortion in said vibrating means.

2. Apparatus of the character described comprising vibrating means, first motor means for driving said vibrating means, second motor means for driving said vibrating means, said first motor means being magnetic and said second motor means being capacitive, first sensing means operatively coupled to said first motor means for generating a first distortion-compensating signal, second sensing means for generating a second distortion-compensating signal representative of the motion of said vibrating means throughout substantially its entire extent; said second sensing means comprising a capacitor having two relatively movable juxtaposed members, one member including a conductive surface fixed to said vibrating means and apportioned to be representative of substantially the entire vibrating extent of said vibrating means, the other member fixed in relation to said vibrating means, said two members constituting at least a two plate capacitor so as to sense for error throughout substantially the entire extent of said vibrating means, means for utilizing both said distortion-compensating signals for reducing to a

minimum motional distortion in said vibrating means, and means for applying both of said distortion-compensating signals to both of said motor means.

3. Apparatus of the character described comprising a vibrating element which vibrates throughout its extent, voice coil means for driving said element, capacitor means for driving said element in cooperation with said voice coil means, feedback coil means operatively coupled to said vibrating element for generating a signal corresponding to the motion of said element, and feedback capacitor means operatively coupled to said vibrating element for generating a signal corresponding to the motion of said element throughout its extent, said signals having utility in compensating for distortion in said vibrating element.

4. A speaker comprising a flexible diaphragm, voice coil means coupled to said diaphragm, feedback coil means connected to said voice coil means for moving in unison therewith, a magnetic driver having a flux-conducting element, said voice coil means and said feedback coil means being operatively coupled to said flux-conducting element, a metallic plate-like frame supporting said diaphragm and being spaced therefrom, said diaphragm being conductive whereby a two-plate capacitor is formed with said frame, and at least one sensing plate disposed in spaced relation with respect to said diaphragm and extending from a point adjacent to the peripheral edge of said diaphragm to a point adjacent to the center of said diaphragm thereby forming a second capacitor, said feedback coil means and said second capacitor generating signals representative of the motion of said diaphragm substantially throughout its vibrating extent.

5. A speaker comprising a flexible planar diaphragm, voice coil means coupled to said diaphragm, feedback coil means connected to said voice coil means for moving in unison therewith, a magnetic driver having a flux-conducting element, said voice coil means and said feedback coil means being operatively coupled to said flux-conducting element, a metallic plate-like frame supporting said diaphragm and being spaced therefrom, said frame being more closely spaced to said diaphragm in the outer peripheral regions than in the inner regions, said diaphragm being conductive whereby a two-plate capacitor is formed with said frame, and a sensing plate disposed in spaced relation with respect to said diaphragm and extending from a point adjacent to the peripheral edge of said diaphragm to a point adjacent to the diaphragm center thereby forming a second capacitor, said feedback coil means and said second capacitor generating signals representative of the motion of said diaphragm over substantially its entire vibrating extent.

6. A speaker comprising a flexible planar diaphragm, voice coil means coupled to said diaphragm, feedback coil means connected to said voice coil means for moving in unison therewith, a plate of magnetic material having two concentric air gaps, one air gap receiving said voice coil means and the other air gap receiving said feedback coil means, a magnet coupled to said plate for providing a flow of flux therethrough, a metallic plate-like frame supporting said diaphragm and being spaced therefrom, said diaphragm being conductive whereby a two-plate capacitor is formed with said frame, and a sensing plate disposed in spaced relation with respect to said diaphragm thereby forming a second capacitor, said feedback coil means and said second capacitor generating signals representative of the motion of said diaphragm.

7. A speaker comprising a flexible planar diaphragm, the central portion of said diaphragm being stiffer than the radially outer portions, voice coil assembly secured to said stiffened portion, feedback coil assembly coaxially disposed with respect to said voice coil assembly and being coupled for movement therewith, a plate of magnetic material having two concentric air gaps, one air gap reciprocably receiving said voice coil assembly and the other air gap reciprocably receiving said feedback coil assembly, a magnet coupled to said plate for providing a flow of flux through both air gaps, a metallic plate-like frame supporting said diaphragm and being spaced therefrom, said diaphragm being conductive thereby forming a two-plate capacitor with said frame, and a sensing plate disposed in spaced relation with respect to said diaphragm and extending from a point adjacent to the peripheral edge of said diaphragm to a point adjacent to the diaphragm center thereby forming a second capacitor, and means coupling said feedback coil assembly and said second capacitor in parallel, said feedback coil assembly and said second capacitor cooperating to generate a signal representative of the motion of substantially all parts of said diaphragm.

8. A speaker comprising a flexible planar diaphragm, the central portion of said diaphragm being stiffer than the radially outer portions, voice coil means secured to said stiffened portion, feedback coil means coaxially disposed with respect to said voice coil means and being coupled for movement therewith, a plate of magnetic material having two concentric air gaps, one air gap reciprocably receiving said voice coil means and the other air gap reciprocably receiving said feedback coil means, a magnet coupled to said plate for providing a flow of flux through both air gaps, a metallic plate-like frame supporting said diaphragm and being spaced therefrom, said diaphragm being conductive thereby forming a two-plate capacitor with said frame, and a sensing plate disposed in spaced relation with respect to said diaphragm and extending from a point adjacent to the peripheral edge of said diaphragm to a point adjacent to the diaphragm center thereby forming a second capacitor, said voice coil means and the first-mentioned capacitor being operatively coupled in parallel for driving cooperatively said diaphragm, and said second capacitor and said feedback coil means being operatively coupled in parallel to generate signals representative of the motion of substantially all parts of said diaphragm.

9. Transducing apparatus comprising a flexible planar diaphragm, the central portion of said diaphragm being stiffer than the other portions, a magnetically driven motor operatively coupled to said central portion, an electrostatically driven motor operatively coupled to said other portions, inductive means for generating a signal representative of distortional vibration in said central portion, and capacitive means for generating a signal representative of distortional vibration in said other portions.

10. Transducing apparatus comprising a flexible diaphragm, the central portion of said diaphragm being stiffer than the other portions, a magnetically driven motor operatively coupled to said central portion, an electrostatically driven motor operatively coupled to said other portions, inductive means for generating a signal representative of distortional vibration in said central portion, capacitive means for generating a signal representative of distortional vibration in said other portions, and means for utilizing both of said signals to produce a compensated signal for correcting distortional motion of said diaphragm.

11. Apparatus of the character described comprising vibrating means, first motor means for driving said vibrating means, second motor means for driving said vibrating means, said first motor means being magnetic and said second motor means being capacitive, first sensing means operatively coupled to said first motor means for generating a first distortion-compensating signal, second sensing means operatively coupled to said vibrating means for generating a second distortion-compensating signal, and an amplifier having input and output circuits, means coupling said first and second motor means to said output circuit, means coupling said first and second sensing means in a degenerative sense to said input circuit thereby compensating for distortion appearing on said vibrating means.

12. A speaker apparatus comprising a flexible planar diaphragm, a plate of magnetic material having two concentric air gaps, a coil form received by one of said air gaps for reciprocation therein, a voice coil on said coil form disposed in said air gap, said coil form being connected to said diaphragm, a feedback coil operatively connected to said coil form for moving in unison therewith, said feedback coil being disposed in the other air gap, a pair of spaced magnetic members providing a third air gap which is axially spaced from and coaxial with said one air gap, said coil form extending into said third air gap, a driving coil on said coil form and disposed in said third air gap, a magnet coupled to said plate and to said pair of magnetic members, a metallic plate-like frame fixedly secured to said magnetic plate and supporting said diaphragm and being spaced therefrom, an amplifier comprising two electron discharge devices having electron collecting and electron emitting elements respectively, said voice coil comprising a quadrifiliar winding having four interwound inductors, one of said inductors being series-connected between an electron-collecting element of one tube and a source of supply potential, a second of said inductors being series-connected between the electron-collecting element of the other tube and a source of supply potential, a third of said inductors being series-connected between the electron-emitting element of one tube and a source of reference potential, and the fourth of said inductors being series-connected between the electron-emitting element of the other tube and said source of reference potential.

13. Apparatus of the character described comprising vibrating means, first motor means for driving said vibrating means, second motor means for driving said vibrating means, means for driving the first motor means from the second motor means, first sensing means operatively coupled to said first motor means for generating a first distortion-compensating signal, and second sensing means for generating a second distortion-compensating signal, said second sensing means including means for sensing motion of said vibrating means throughout substantially the entire vibrating extent thereof, means utilizing both distortion-compensating signals for reducing to a minimum motional distortion in said vibrating means.

14. Apparatus of the character described comprising vibrating means, first motor means for driving said vibrating means, second motor means for driving said vibrating means, driving means physically coupled to said first motor means for generating a signal representative of the actuation of said first motor means, said driving means being coupled to said second motor means, and means for driving the first motor means from the second motor means.

15. Apparatus of the character described comprising a vibrating element, voice coil means for driving said element, capacitor means for driving said element in cooperation with said voice coil means, and secondary coil means directly coupled to said vibrating element for generating a signal corresponding to the motion of said element, said secondary coil means being operatively coupled to said capacitor means for driving the latter.

16. Apparatus of the character described comprising a vibrating element, voice coil means for driving said element, capacitor means for driving said element in cooperation with said voice coil means, and secondary capacitor means directly coupled to said vibrating element for generating a signal corresponding to the motion of said element, said secondary capacitor means being operatively coupled to said voice coil means for driving the latter.

17. A speaker system comprising a flexible planar diaphragm, a plate of magnetic material having two concentric air gaps, a coil form received by one of said air gaps for reciprocation therein, a voice coil on said coil form disposed in said air gap, said coil form being connected to said diaphragm, a feedback coil on a second coil form connected to said diaphragm for moving in unison therewith, said feedback coil being disposed in the other air gap, a pair of spaced magnetic members providing a third air gap which is axially spaced from and coaxial with said one air gap, said coil form extending into said third air gap, a driving coil on said coil form and disposed in said third air gap, a magnet coupled to said plate and to said pair of magnetic members, a metallic plate-like frame fixedly secured to said magnetic plate and supporting said diaphragm and being spaced therefrom, said diaphragm being conductive whereby a two-plate capacitor is formed with said frame, a sensing plate spaced from said diaphragm and extending radially thereover thereby forming a second capacitor, and an amplifier connecting said driving coil to said diaphragm and frame.

18. A speaker system comprising a flexible planar diaphragm, a plate of magnetic material having two concentric air gaps, a coil form received by one of said air gaps for reciprocation therein, a voice coil on said coil form disposed in said air gap, said coil form being connected to said diaphragm, a feedback coil on a second coil form connected to said diaphragm for moving in unison therewith, said feedback coil being disposed in the other air gap, a magnet coupled to said plate for providing a flow of flux through said air gaps, a metallic plate-like frame supporting said diaphragm and being spaced therefrom, said diaphragm being conductive whereby a two-plate capacitor is formed with said frame, a sensing plate spaced from said diaphragm and extending radially thereover thereby forming a second capacitor, a plurality of interleaved conductive plate-like elements insulated one from the other disposed between said diaphragm and said frame, alternate ones of said elements being connected together thereby forming a third capacitor which will generate a signal in response to movement of said diaphragm, and a circuit connecting said third capacitor to said driving coil.

19. A device of the character described comprising vibrating means, first motor means for driving said vibrating means, second motor means for driving said vibrating means, means for driving the first motor means from the second motor means, first sensing means operatively coupled to said first motor means for generating a first distortion-compensating signal, and second sensing means operatively coupled to said second motor means for generating a second distortion-compensating signal, and an amplifier having input and output circuits, said first and second sensing means being operatively coupled in a degenerative sense to said input circuit, and said first and second motor means being operatively coupled to said output circuit.

20. A speaker apparatus comprising a flexible planar diaphragm, a plate of magnetic material having two concentric air gaps, a coil form received by one of said air gaps for reciprocation therein, a voice coil on said coil form disposed in said air gap, said coil form being connected to said diaphragm, a feedback coil operatively connected to said coil form for moving in unison therewith, said feedback coil being disposed in the other air gap, a pair of spaced magnetic members providing a third air gap which is axially spaced from and coaxial with said one air gap, said coil form extending into said third air gap, a driving coil on said coil form and disposed in said third air gap, a magnet coupled to said plate and to said pair of magnetic members, a metallic plate-like frame fixedly secured to said magnetic plate and supporting said diaphragm and being spaced therefrom, said diaphragm having a conductive surface thereby proving a two-plate electrostatic motor with said frame, an amplifier comprising two electron discharge devices having electron collecting and electron emitting elements respectively, said voice coil comprising a quadrifilar winding having four interwound inductors, one of said inductors being series-connected between an electron-collecting ele-

ment of one tube and a source of supply potential, a second of said inductors being series-connected between the electron-collecting element of the other tube and a source of supply potential, a third of said inductors being series-connected between the electron-emitting element of one tube and a source of reference potential, and the fourth of said inductors being series-connected between the electron-emitting element of the other tube and said source of reference potential.

21. For use in a speaker, a vibrator, a quadrifilar voice coil operatively connected to said vibrator, an amplifier comprising two electron discharge devices having electron collecting and electron emitting elements respectively, said voice coil comprising a quadrifilar winding having four interwound inductors, one of said inductors being series-connected between an electron-collecting element of one tube and a source of supply potential, a second of said inductors being series-connected between the electron-collecting element of the other tube and a source of supply potential, a third of said inductors being series-connected between the electron-emitting element of one tube and a source of reference potential, and the fourth of said inductors being series-connected between the electron-emitting element of the other tube and said source of reference potential.

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