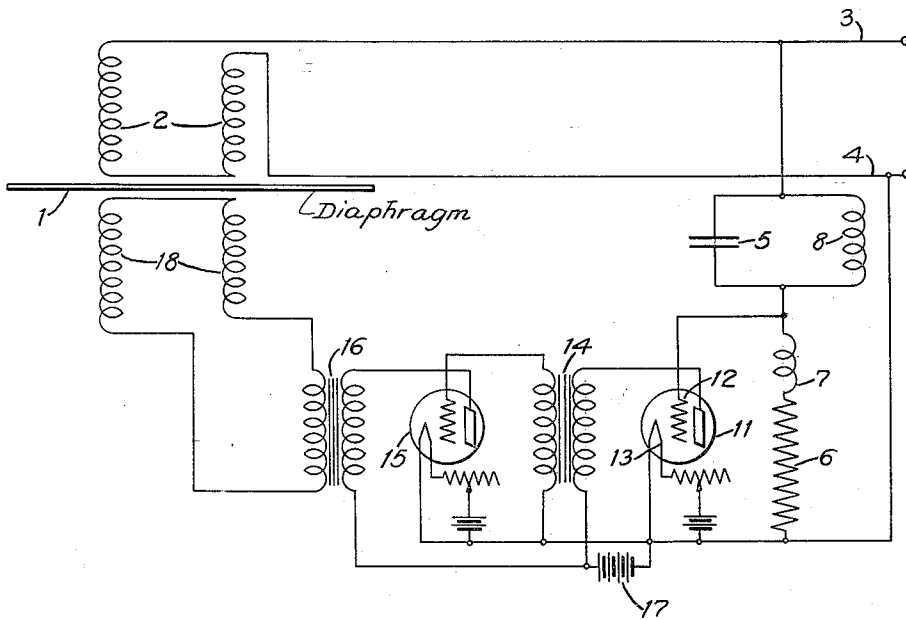


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SOUND TRANSLATING DEVICE

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SOUND-TRANSLATING DEVICE.

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This invention relates to sound translating systems including microphones and particularly microphones of the type which have vibrating diaphragms.

5 One object of this invention is to increase the faithfulness with which the output of the translating system represents the impressed sound and to extend the range of frequencies over which such representation is faithful.

10 It is a further object of this invention to provide means for exerting, upon the diaphragm, a force which is a function of the electromotive force generated by the movement of the diaphragm.

15 A further object of this invention is to provide a thermionic amplifier, the input of which is controlled by the electromotive force generated by the diaphragm and the output of which energizes an electromagnetic device, which, in turn, acts upon the diaphragm.

20 When a diaphragm moves, under the varying pressure due to sound, three forces are brought into play, beside the driving pressure: (1) the reaction due to the mass of the diaphragm, which is proportional to, and in phase with, the acceleration, and the direction of which is opposite to the acceleration; (2) the "stiffness" reaction due to the elasticity of the diaphragm, which is proportional to, and in phase with, the displacement, and the direction of which is toward the mid-position of the diaphragm; and (3) the damping. It is an object of this invention to exert forces upon the diaphragm which shall counteract the reactions due to mass and stiffness, respectively.

25 At frequencies below the natural period of the diaphragm, the reaction due to stiffness predominates, while, at frequencies above the natural period, the reaction due to mass predominates. It is an object of this invention to provide a compensating device in which the force tending to compensate for the reaction due to stiffness shall predominate at low frequencies and the force tending to counteract the reaction due to mass shall predominate at higher frequencies.

30 A further object of this invention is to provide a means by which the forces tending to counteract these reactions shall be absent

at the natural fundamental, resonance period of the diaphragm.

A further object of this invention is to provide means for preventing the forces, intended to counteract the said reactions, from driving the diaphragm. Thus, the combination is prevented from becoming unstable.

A further object of this invention is to provide a means for preventing the forces, impressed upon the diaphragm to counteract said reactions, from having any component in phase with the velocity of the diaphragm.

Other objects of the invention and details of the structure will be apparent from the following description and the accompanying drawing in which:

The single figure is a diagram illustrating the circuits employed in this invention.

70 The translating system includes a diaphragm 1, which is intended to be vibrated by sound. A coil 2, adjacent to the diaphragm 1 is so related thereto that movement of the diaphragm will generate an electromotive force in the coil. The illustration of the diaphragm and coil is wholly diagrammatic and is intended to represent any arrangement, in which the movement of the diaphragm causes a corresponding electromotive force in the coil. The arrangement, to which the drawing most nearly corresponds, namely one in which the diaphragm, by its motion, changes the length of the air-gap and so alters the flux through the coil, is not the only one contemplated.

75 The electromotive force generated in the coil 2 is delivered to the conductors 3 and 4, which extend to the terminals of the device and are comprised in the output circuit. Across the conductors 3 and 4 is a shunt, including a condenser 5 and a resistor 6. The condenser is so small that its reactance constitutes nearly all of the impedance in the shunt through the condenser 5 and the resistor 6. A small inductor 7 is provided in series with the resistor 6.

80 An inductor 8 is provided in parallel with the condenser 5. The inductor is so large that its reactance constitutes nearly all of the impedance in the shunt through it and resistor 6. The combined impedance of the condenser 5 and the inductor 8 is great enough to be the largest part of the imped-

ance in the shunt, even when both condenser 5 and inductor 8 are present. Either of these two reactors may be omitted if desired.

The vacuum-tube device 11 has its grid circuit connected across the inductor 7 and the resistor 6. Consequently, the potential difference between the grid 12 and the cathode 13 is equal to the drop over the portion of the shunt between the reactors 5 and 8 and the conductor 4.

The output of the thermionic amplifier 11 supplies an audio-frequency transformer 14 which feeds the input of the thermionic tube 15. The output of this tube supplies a second audio-frequency transformer 16. The energy delivered by the audio-frequency transformer 16 is derived from the source 17 of energy for the amplifier. Consequently, the energy delivered by the transformer 16, although it is controlled by the potential in the output of the microphone, is obtained from a distinct source and is not a part of the energy in said output.

The transformer 16 supplies an electromagnetic device 18 which acts upon the diaphragm 1.

Although we have illustrated the electromagnetic device 18 as a magnet acting directly upon the iron diaphragm 1, the invention is equally applicable to any form of electromagnetic device which can exert force upon the diaphragm. For example, the coil 18 may act upon an armature, which, in its turn, is mechanically connected to the diaphragm.

The coil 2 and the magnet 18 should have very little or no magnetic coupling. If, as shown in the diagram, they are on opposite sides of the diaphragm, the paths through the iron diaphragm from one half of the winding 18 to the other will have so much smaller reluctance than the path across the air gap from winding 18 to winding 2 that there will be little inductive coupling of the two windings.

In the operation of the device, the diaphragm 1 is driven by the varying pressure exerted by the sound and generates an electromotive force in the coil 2 which is proportional to and approximately in phase with, the velocity of the diaphragm. Since the condenser 5 constitutes nearly all of the impedance in the shunt path which includes the condenser, the current through it may, without material error, be called proportional to the rate of change of potential in the output circuit including conductors 3 and 4. It is, therefore, proportional to the acceleration of the diaphragm. The phase of the current through the condenser leads the potential by 90°. The acceleration of the diaphragm leads its velocity by 90°. The current through the condenser is, therefore, approximately in phase with the acceleration of the diaphragm.

The potential upon the grid 12 is deter-

mined by the drop across the inductor 7 and the resistor 6. For the moment we will ignore the effect of the inductor 8 and consider the magnitude and phase of this drop as determined by the condenser 5, unshunted. The impedance of the inductor 7 is small compared with that of the resistor 6. The current in the resistor is in phase with the current in the condenser. The phase of the potential across the resistor will be only approximately that of the acceleration, as will be explained later in connection with the reason for the inductor 7.

The potential changes upon the grid 12 are amplified, and the resulting currents in the magnet 18 will correspond accurately in amount, and approximately in phase, to the acceleration of the diaphragm. The effect, therefore, of the combination, including the condenser 5, but ignoring inductor 8, is to cause the magnet 18 to exert a force which, at all times, tends to overcome the reaction, due to mass, in the diaphragm 1.

The current in the inductor 8 is proportional to, and in phase with, the displacement of the diaphragm. This is best understood from the equation for electromotive forces in the circuit 2, 3, 8, 7, 6, 4, 2. This is

$$M \frac{dx}{dt} = i r + L_7 \frac{di}{dt} + L_8 \frac{di}{dt}, \quad 95$$

where M is the proportionality constant, relating the displacement x to the electromotive force developed in the coil 2. Of the other quantities, $i r$ is the drop in resistor 6, and

$$L_7 \frac{di}{dt} \quad 105$$

is the drop in the inductor 7 and are both so small they may be neglected. Only

$$L_8 \frac{di}{dt}, \quad 110$$

which is the drop in the inductor 8, remains on the right hand side of the equation. Integrating the equation, therefore, gives directly

$$i = \frac{M}{L} x \quad 115$$

The current through the resistor 6, if the condenser 5 be ignored, is in phase with the current in the inductor 8. The potential upon the grid 12, therefore, so far as the effect of the inductor 8 is concerned, is proportional to the displacement of the diaphragm. It is nearly in phase with the displacement but not exactly so, because of the effect of the inductor 7 which is discussed below. This potential, amplified and applied to the magnet 18, will produce a force on the diaphragm approximately in phase

with the displacement and in the direction of the displacement. This force, therefore, tends to overcome the reaction due to the elasticity of the diaphragm; that is, it tends to counteract the stiffness.

The condenser 5, used without the inductor 8, causes the magnet 18 to tend to counteract the mass reaction. The inductor 8, used without the condenser 5, causes the magnet 18 to tend to overcome the stiffness reaction. When both the condenser 5 and the inductor 8 are used, both tendencies will be simultaneously present. At low frequencies, more current passes through the inductor 8 than through the condenser 5. At low frequencies, therefore, the magnet 18 has a greater tendency to overcome the reaction due to the stiffness than to overcome that due to mass. At frequencies above the natural fundamental, resonance period of the diaphragm, more current flows through the condenser 5 than through the inductor. The tendency of the magnet 18 to overcome the reaction due to mass, is greater, at these frequencies, therefore, than its tendency to overcome the reaction due to stiffness. This is as it should be; because, at frequencies above the natural period of the diaphragm, the reaction due to mass predominates, while, at frequencies below resonance, the reaction due to stiffness predominates.

At the resonant period of the diaphragm, the circuit 5—8 is parallel-resonant and passes practically no current. The magnet 18, therefore, at this frequency, tends to overcome neither reaction. This is the desired effect; because, at the natural resonance period, the diaphragm will vibrate to a maximum amount, and, therefore, should have no assistance from the source of auxiliary energy.

Because of certain small effects, the electromotive force developed in the coil 2 is not strictly in phase with the velocity of the diaphragm. Moreover, the force exerted by the magnet 18 upon the diaphragm 1 is not strictly in phase with the current in the magnet. If these phase-differences are sufficient to cause the force exerted by the magnet 18 to lag behind the acceleration of the diaphragm, there will be a component of this force in phase with the velocity. Consequently, there will be a tendency for the magnet to increase the amplitude of the diaphragm movement.

This increased amplitude will produce a greater action by the magnet 18 which will produce a further increase in the movement of the diaphragm, and so on. Such a condition will cause the system to be unstable; that is, a small displacement would result in the system setting up and continuing oscillations independent of the impressed sound.

It is to avoid this undesirable instability that the inductor 7 is introduced in series with the resistor 6. The phase of the drop across the combination of inductor 7 and resistor 6 will lead that of the current through said combination. The phase of the potential changes upon the grid 12 is corrected by this means. This ensures that the force exerted by the magnet 18 will either be in phase with the acceleration of the diaphragm, or will slightly lead the acceleration in phase. The stability of the combination is thus rendered certain.

If the reaction due to mass is to be compensated alone, the inductor 8 is omitted. If only the reaction due to stiffness is to be counteracted, the condenser 5 is omitted. Thus, any desired character of compensation may be obtained.

While we have shown only one embodiment of our invention in the accompanying drawings, it is capable of various changes and modifications without departing from the spirit thereof, and it is intended, therefore, that only such limitations shall be imposed thereon as are necessitated by the prior art or indicated in the appended claims.

We claim as our invention:

1. In a sound-responsive device, a diaphragm, means for generating an electromotive force by the movement of said diaphragm, output conductors to which said electromotive force is applied, a shunt across said conductors including a reactor and a resistor, an amplifier controlled by the potential drop in said resistor and an electromagnetic device energized by said amplifier and exerting force on said diaphragm.

2. In a sound-responsive device, a diaphragm, means for generating an electromotive force by the movement of said diaphragm, output conductors to which said electromotive force is applied, a shunt across said conductors including a capacitative reactor and a resistor, an amplifier controlled by the potential drop in said resistor and an electromagnetic device energized by said amplifier and exerting force on said diaphragm.

3. In a sound-responsive device, a diaphragm, means for generating an electromotive force by the movement of said diaphragm, output conductors to which said electromotive force is applied, a shunt across said conductors including an inductive reactor and a resistor, an amplifier controlled by the potential drop in said resistor and an electromagnetic device energized by said amplifier and exerting force on said diaphragm.

4. In a sound-responsive device, a diaphragm, means for generating an electromotive force by the movement of said diaphragm, output conductors to which said electromotive force is applied, a shunt across

said conductors including a capacitative reactor and an inductive reactor in parallel and a resistor in series therewith, an amplifier controlled by the potential drop in said resistor and an electromagnetic device energized by said amplifier and exerting force on said diaphragm.

5. In a sound-responsive device, a diaphragm, means for generating an electromotive force by the movement of said diaphragm, output conductors to which said electromotive force is applied, a shunt across said conductors including a reactor and a resistor and an inductor in series therewith, an amplifier controlled by the potential drop in said resistor and inductor, and an electromagnetic device energized by said amplifier and exerting force on said diaphragm.

6. In a sound translating system, a sound-responsive moving member, output conductors, an amplifier having its input connected to said output conductors and an electromagnetic device fed by the output of said amplifier and acting on said moving member, the connection to said amplifier input including a condensive reactor.

7. In a sound translating system, a sound-responsive moving member, output conductors, an amplifier having its input connected to said output conductors and an electromagnetic device fed by the output of said amplifier and acting on said moving member, the connection to said amplifier input including an inductive reactor.

8. In a sound translating system, a sound-responsive moving member, output conductors, an amplifier having its input connected to said output conductors and an electromagnetic device fed by the output of said amplifier and acting on said moving member, the connection to said amplifier input including a condensive reactor and an inductive reactor in parallel.

9. In a sound translating system, a sound-responsive moving member, output conductors, an amplifier having its input connected to said output conductors and an electromagnetic device fed by the output of said amplifier and acting on said moving member, the connection to said amplifier input including a condensive reactor and an inductive reactor in parallel, and constituting a parallel-resonant circuit at the frequency of the fundamental of said sound-responsive moving member.

10. In a sound translating system, a sound-responsive movable member, a device controlled by the output of the system for impressing a force upon said member and a phase-determining means preventing said force from lagging behind the acceleration of said member.

In testimony whereof, we have hereunto subscribed our names this 25th day of August, 1924.

JOSEPH SLEPIAN.
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