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VIBRATORY SYSTEM

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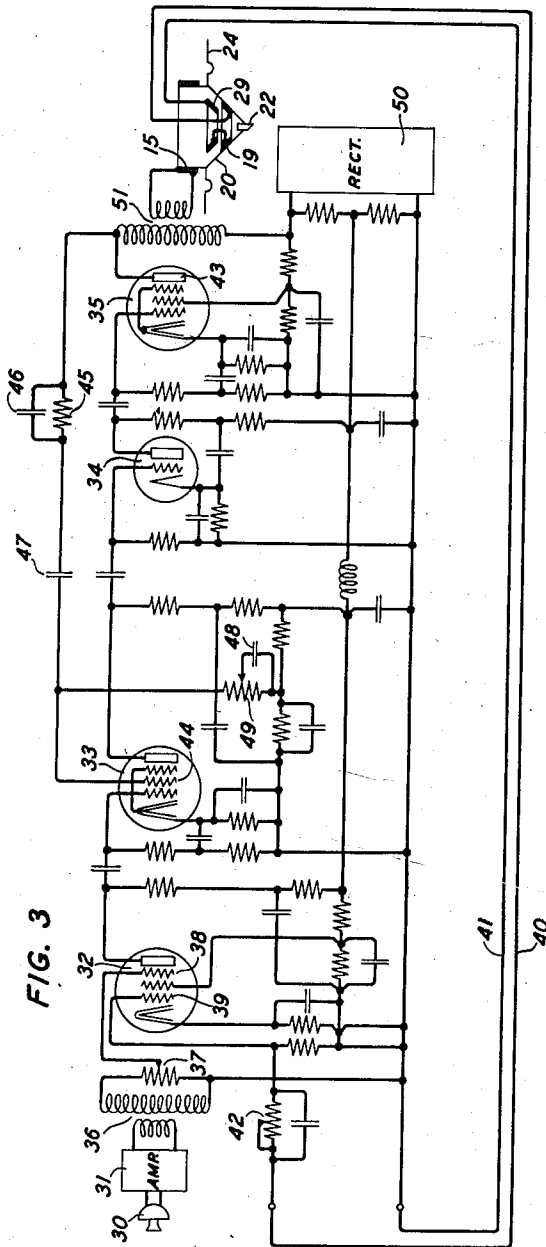


FIG. 7

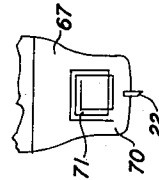


FIG. 6

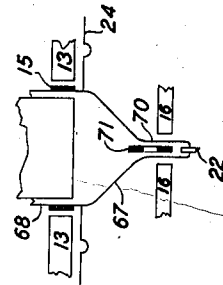


FIG. 5

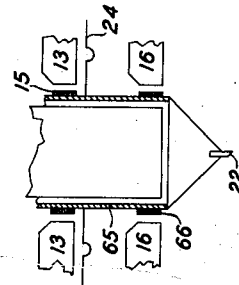
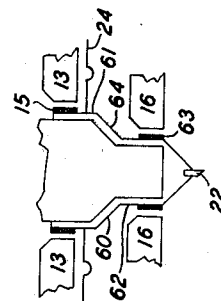


FIG. 4



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VIBRATORY SYSTEM

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9 Claims. (Cl. 179-100.41)

This invention relates to electrically-driven vibratory systems, particularly phonograph recording systems.

It has been proposed heretofore to stabilize the operation of amplifiers and reduce the distortion in their outputs by means of negative feedback, that is, by feeding back a portion of the amplifier output to the input circuit in phase opposition to the signal energy in the input circuit. The theory of operation of such amplifiers is discussed, for example, by H. S. Black in the Bell System Technical Journal for January 1934. It has also been proposed to apply this principle to electrically-driven mechanically vibrating systems by deriving the feedback energy from a generating element moving with the driven system. While the theoretical requirements for such a system have been understood for some time, great difficulty has been encountered in devising a stable practical system of this type which will give satisfactory results when operating over a wide range of frequencies.

The object of this invention is a stable, electro-mechanical vibrating system of the negative feedback type which is capable of substantially distortionless response over the high quality range of frequencies of speech and music.

According to this invention, in order to simplify the problem of maintaining proper phase relations in the feedback circuit, the vibratory system is designed to have only a single resonant peak over the operating range and secondary effects due to resonances of air chambers adjacent to the moving system are avoided by providing paths for the flow of air through the system while it is vibrating. Stable operation is obtained in a compact structure by shielding the feedback element from the main driving element and when necessary any remaining inductive effect of the driving element on the output of the feedback element may be balanced out as explained below.

In the preferred structure for a phonograph recorder the moving system comprises a large driving coil, a smaller feedback coil and a stylus rigidly interconnected by a stiff conical member which is supported for vibration by spaced resilient supports such as a diaphragm and a cantilever spring. A magnet having pole-pieces defining spaced air-gaps provides the necessary flux for the coils and a copper plate between the outer pole-pieces and a copper facing for the inner pole-pieces constitute a substantially continuous shield between the coils. When necessary for stability of operation a third stationary coil is

mounted on the central pole-piece near the feedback coil and connected with it in opposing relationship in the feedback circuit. Due to the compactness of the structure and the necessity of using small air-gaps to obtain high efficiency, the moving system has adjacent to it a number of small air chambers. The stiffness of the air entrapped in these chambers would ordinarily be such as to resonate with the mass of the moving system of the recorder or with the mass of the air itself to produce secondary resonance effects which would cause singing or irregularities in the response. To prevent these undesirable effects the air stiffness of these chambers is reduced according to the invention by providing a large number of small perforations in the diaphragm and driving cone.

The fundamental requirement for the stable operation of such a system is that the total phase shift in the amplifier and recorder shall be less than plus or minus 180 degrees over the entire band of frequencies to be transmitted for all conditions in which the gain around the loop comprising the amplifier, the recorder and the feedback coil is greater than unity. Since the use of a moving system with a single resonant frequency with respect to its support is an important aid in keeping the phase shift within the limits stated above, it is important that the member connecting the coils to the stylus and the resilient suspension for the coil be stiff enough to avoid all secondary resonances within the operating range.

These and other features of the invention will be more clearly understood from the following detail description and the accompanying drawings in which:

Fig. 1 is a phonograph recorder, according to the invention;

Fig. 2 is an enlarged sectional view showing the vibratory system of the recorder;

Fig. 3 is a schematic of a recording system including the recorder of this invention; and

Figs. 4 to 7 show other vibratory systems which may be used in recorders of this type.

Referring to Figs. 1 and 2, the magnet 11 has a central pole-piece 12 and an outer pole-piece 13 defining an annular gap 14 for the main signal driving coil 15 and a second outer pole-piece 16 which, with the extension piece 17 on the central pole-piece, defines a gap 18 for the feedback coil 19. The stiff cone member 20 on which the coils are mounted is fitted at its apex with a holder 21 for a stylus 22 and with a V-shaped cantilever spring 23, of the type shown in Patent

2,055,187 granted to L. Vieth September 22, 1936, secured to the pole-piece 16 for holding the vibratory system in correct alignment. The whole system is also supported for vertical vibration by a diaphragm 24 having a stiffening corrugation 25 for preventing local resonance effects.

The feedback coil 19 is shielded from the field set up by the driving coil 15 by a copper ring 26 between the pole-pieces and a second copper ring 27 surrounding the pole-piece extension 17. These rings and pole-pieces define adjacent the diaphragm 24 and the cone 20 a number of small air chambers which would ordinarily introduce resonance effects due to the stiffness of the confined air. These resonances are avoided in this recorder by providing the diaphragm and the cone with a larger number of small perforations 28 which allow the air to flow through the vibrating system and thereby reduce the air stiffness to a value which is not objectionable.

Since the clearances around the vibrating system are made as small as practical in order to obtain high flux density in the air-gaps, the rings 26 and 27 constitute between the driving and feedback coils a substantially continuous copper shield which is very effective at the higher frequencies where shielding is most necessary. If the shielding effect so obtained, however, is not complete enough, particularly at lower frequencies, it may be desirable to provide a third coil 29 in a recess in the ring 27 and adjacent the feedback coil so as to have substantially the same mutual inductance as the latter with the driving coil. This coil when used is then connected in the feedback circuit in serially opposing relation to the feedback coil.

In a copending application of C. F. Wiebusch Serial No. 10,737, filed Oct. 7, 1937, it is pointed out that in feedback systems of this type which involve a double conversion of energy, namely from electrical to mechanical and back to electrical energy, a very high gain is required around the feedback path in order to obtain a flat response characteristic. In obtaining this high gain care must be taken not to complicate unnecessarily the problem of keeping the feedback negative. As is well known, each vacuum tube produces a 180 degree phase shift and other components of the system, such as the output transformer 39, introduce further phase shifts which vary with frequency so that careful design and adjustment of the recorder and its driving amplifier as a unit is necessary to keep the system stable over the wide frequency range required for high quality recording.

In the circuit of Fig. 3 which shows an amplifying system which has been found to work satisfactorily with this recorder, the currents representing the signal to be recorded are derived from any suitable source such as a microphone 30 and are amplified to some intermediate level by an amplifier 31 in the usual manner. The output of this amplifier passes through the tube 32 where it is combined with the feedback energy from the recorder as more fully explained below, and through the necessary additional amplifier stages such as 33, 34 and 35 to the driving coil 15 of the recorder. The vibrating system of the recorder drives the stylus to cut a record in accordance with the impressed signal currents and also drives the feedback coil 19 to generate a voltage which is proportional to the stylus velocity.

The incoming signals from the amplifier 31, which are already at a fairly high energy level, are applied through the transformer 36 and vol-

ume control 37 to the suppressor grid 38 of the tube 32, and the feedback voltage from the coil 19 is applied to the control grid 39 through conductors 40, 41 and (when required) a suitable adjustable phase shifting network 42. In this way the gain around the feedback path is made higher than the gain for the incoming signals without adding any additional amplifier stages in the feedback loop.

As a further aid in stabilizing the system and obtaining an overall flat response, the amplifying system may be provided with an internal negative feedback path extending from the plate 43 of the tube 35 to the screen grid 44 of the tube 33. This circuit may comprise a resistor 45 shunted by a condenser 46 and the second condenser 47 in series therewith in the connection to the screen grid 44 and a condenser 48 shunting an adjustable portion of the resistor 49 which supplies potential to the grid 44 from the rectifier 50 in the usual manner. The capacity of the condenser 48 is such as to decrease the feedback at high frequencies and keep the response of the recorder at the proper level in the region where it would otherwise tend to droop and the small condenser 46 controls the phase shift to prevent the feedback from becoming positive and producing instability at super-audible frequencies. This internal feedback loop also reduces harmonic distortion, improves the impedance matching between the tube 35 and the recorder and also reduces the objectionable phase shift of the output transformer 51.

While the member 20 carrying the coils 15 and 19 and the stylus 22 of the recorder has been shown and described as a stiff cone, this singly resonant member may take other forms, some of which are shown in Figs. 4 to 7. In Fig. 4 the member 60 comprises an upper cylindrical portion 61 for the coil 15 and a lower cylindrical portion 62 for the feedback coil 63 joined together by the conical portion 64. In the structure of Fig. 5 a single cylindrical portion 65 mounts both the signal coil 15 and the feedback coil 66 which, like the coil 63 of Fig. 4, is also of the cylindrical type. These coils are not only easier to make and mount than the coil 19 of Fig. 1, but they also permit the use of a short vertical air-gap which gives a higher flux density at the coil and therefore a higher feedback voltage.

The coil support 67 of Figs. 6 and 7 has an upper cylindrical portion 68 for the driving coil 15 and tapers to a thin rectangular end portion 70 at the stylus 22. Within this flattened portion 70 at right angles to the plane of the coil 15 a rectangular coil 71 is disposed with one side in the gap defined by the pole-pieces 16. Since the two coils of this structure have substantially no mutual inductance, the shielding problem is greatly simplified and in many cases no shielding between the coils will be necessary.

Other modifications in the structure shown will occur to those skilled in the art but the invention is intended to be limited only by the scope of the following claims.

What is claimed is:

1. In a recording device, a magnetic circuit having a central pole-piece and two spaced annular pole-pieces forming air-gaps, a vibratory system comprising driving and driven coils disposed in the gaps, a stylus, a rigid member connecting the coils to the stylus and a resilient support for the member, and stationary means between the pole-pieces for shielding the driven coil from the field of the driving coil.

2. A recording device comprising a magnet system having two annular gaps and a vibratory system including a driving coil in one of the gaps carrying currents representing sounds to be recorded, a driven coil in the other gap for generating currents to control the motion of the vibratory system, a stylus and means for connecting the coils to the stylus, and a third, stationary coil connected in opposed relationship to the driven coil with respect to currents induced therein by the field of the driving coil.

3. In a recording device a magnet system having a central pole-piece and two spaced annular pole-pieces defining gaps and a vibratory system comprising a stylus, a driving coil therefor in one of the gaps, a driven coil in the other gap for controlling the motion of the stylus, a rigid member connecting the coils to the stylus and a resilient support for the member, said member and support defining with the pole-pieces a plurality of small substantially closed air chambers, and perforations in the member and support for reducing the stiffness of the air in the chambers whereby the system has only a single resonant frequency within the operating frequency range of the device.

4. In a vibration translating device a magnetic circuit having a central pole-piece and two spaced annular pole-pieces forming air-gaps, a vibratory system comprising driving and driven coils disposed in the gaps, a driven member and rigid means interconnecting the member and the coils, resilient supporting means for the system and a substantially continuous member of high conductivity extending between the annular pole-pieces and shielding the driven coil from the field of the driving coil.

5. In a recording device a magnetic circuit comprising a magnet having a central pole-piece and an annular pole-piece forming a relatively large upper gap, and a pole-piece extension and

a second annular pole-piece forming a smaller lower gap, a vibrating system comprising a driven member, a driving coil in the upper gap, a driven coil in the lower gap, and rigid means connecting the driven member and driven coil to the driving coil, a resilient support for the vibratory system, shielding means for the driven coil, and a circuit including an amplifier connecting the driven coil to the driving coil.

6. In a feedback recorder, a magnetic circuit defining two spaced air-gaps, a vibrating system comprising a driving coil, a stylus, a feedback coil and means connected to the stylus for mounting the coils for vibration in the gaps and having such mass and stiffness as to have a single resonant frequency within the operating range, and stationary shielding on both sides of the coil mounting means forming a substantially continuous shield between the coils.

7. In a feedback recorder, a magnetic circuit defining two spaced air-gaps, a driving coil in one of the gaps, a resilient support therefor, a stylus, a stiff conical member connecting the coil to the stylus and a feedback coil mounted on the conical member and disposed in the other gap.

8. In a feedback recorder, a magnetic circuit defining two spaced air-gaps, a driving coil in one of the gaps, a resilient diaphragm supporting the coil, a stylus, a stiff conical member connecting the coil to the stylus and a feedback coil disposed in the other gap and mounted adjacent the stylus on the conical member.

9. A vibratory system for feedback recorders comprising a driving coil, a resilient support therefor, a stylus, a rigid member connecting the coil to the stylus and a feedback coil supported by the member and disposed in a plane at right-angles to the plane of the driving coil.

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