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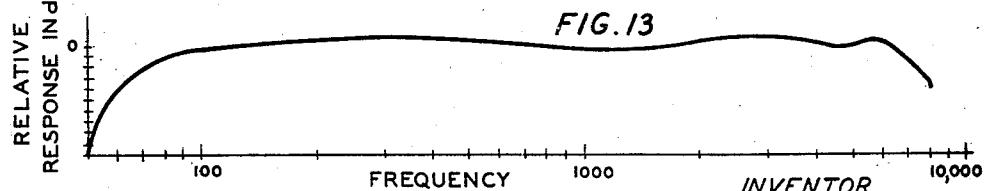
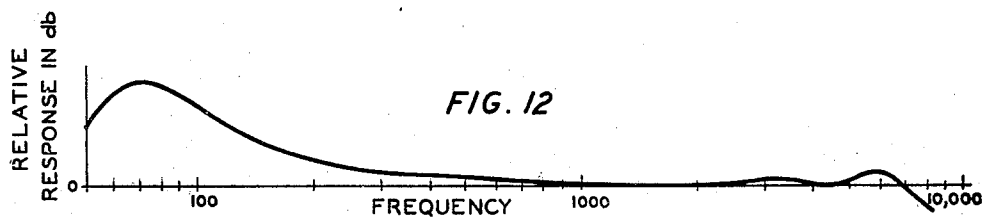
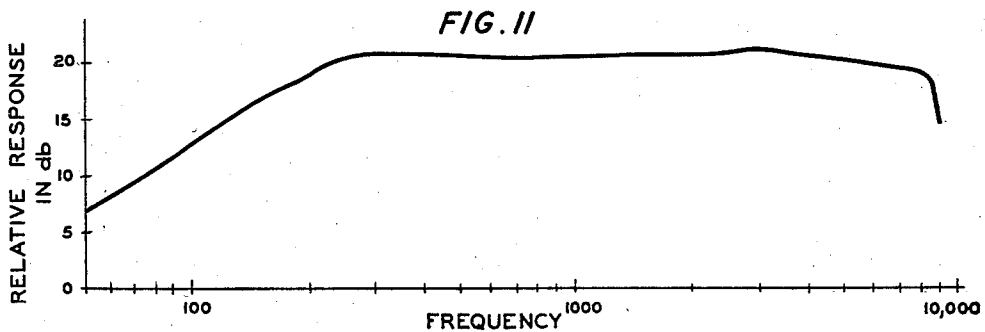
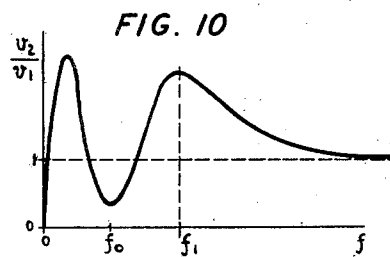
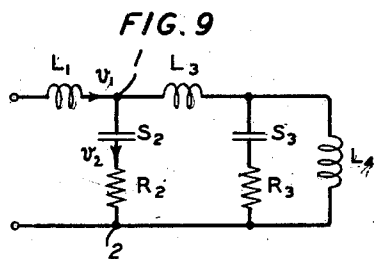
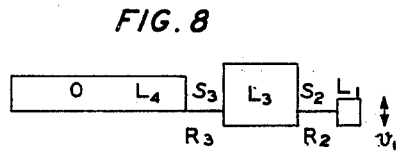
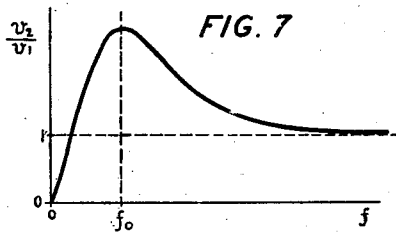
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2,032,194

VIBRATION TRANSLATING DEVICE

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2 Sheets-Sheet 2



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VIBRATION TRANSLATING DEVICE

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6 Claims. (Cl. 179—100.41)

This invention relates to vibration translating systems and more particularly to sound reproducing devices which reproduce with an amplitude-frequency distortion to compensate for distortion in the record.

The phonograph records in common use are said to be recorded at "constant velocity", that is to say, the vibratory velocity of the recorder stylus is constant for sounds of equal intensity irrespective of frequency. This statement is correct for the greater part of the frequency range covered, but for frequencies below 300 or 250 cycles, the groove amplitudes for constant velocity recording become excessive and the usual practice is to attenuate these low frequencies so that, over this part of the frequency range, sounds of equal intensity are recorded at "constant amplitude" instead of constant velocity. In this way the high frequencies can be represented by reasonably large groove amplitudes without causing overcutting at the low frequencies. This arbitrary limitation of groove amplitudes in the record results in an amplitude-frequency distortion of the original sound and when the record is played with a reproducer having a uniform frequency response characteristic, the lower frequencies are noticeably deficient.

To overcome this defect the usual practice is to connect an equalizer or attenuating network in the reproducer circuit to attenuate the higher frequencies to the same relative energy level with respect to the low frequencies, as in the original sound. While such a combination restores the original frequency-amplitude relation of the various components, it increases the cost of the reproducing system by both the cost of the equalizer and the increased capacity required in the amplifying system.

The object of the present invention is to simplify and reduce the cost of systems in which compensatory distortion is necessary.

This object is attained, according to the invention, by eliminating the equalizer network and designing the translating device itself to compensate for the amplitude distortion in the record. One convenient way of producing this compensatory distortion is to couple the elements of the device together in such a way that the normally stationary magnet system is set into vibration out-of-phase with the vibrations of the generating element over the frequency range in which compensation is required so that the low frequency response of the device is increased due to the increase in the relative velocity of the element with respect to the flux.

As applied to phonograph reproducers the invention may take several forms. In its simplest embodiment the vibrating element, such as an armature or coil, is mounted on the normally stationary structure consisting of the magnet system and its pivoted supporting arm, by means of a damped resilient coupling, the stiffness of the coupling and the amount of damping being correlated to the mass of the normally stationary structure to produce the desired increase in the relative velocity over a predetermined frequency range. In a slightly more complicated structure which accomplishes the same result and at the same time permits greater latitude in the choice of mechanical constants, there is provided between the reproducer and its supporting arm a second damped resilient coupling the constants of which are correlated to those of the first and of the normally stationary magnetic structure to produce the desired response characteristic.

In the drawings Fig. 1 is a side view of a moving coil hill and dale phonograph reproducer according to the invention;

Fig. 2 is a front view of the reproducer of Fig. 1;

Fig. 3 is a sectional view of the moving system of the reproducer;

Fig. 4 is a sectional view of the stylus arm and its damping member taken as indicated in Fig. 3;

Fig. 5 is a schematic diagram of a simple form of reproducer according to the invention showing its essential mechanical constants;

Fig. 6 is a circuit showing the mechanical constants of the diagram of Fig. 5 as analogs of the elements of a corresponding electrical circuit;

Fig. 7 is a curve showing the velocity of the moving system of the reproducer of Fig. 5 with respect to the flux at low frequencies;

Fig. 8 is a schematic diagram of a slightly more complicated reproducer according to the invention;

Fig. 9 is a corresponding circuit diagram;

Fig. 10 is the curve showing the velocity of the moving system of the reproducer of Fig. 8 with respect to the flux at low frequencies;

Fig. 11 is the response curve of a typical phonograph recorder;

Fig. 12 is the response curve of a reproducer according to this invention; and

Fig. 13 is the response curve of a reproducer according to the invention when reproducing a record made by a recorder having a characteristic according to Fig. 11.

Referring now to Figs. 1 to 4 the magnet is mounted in a framework having terminals

17, 17 which serve to connect the reproducer both mechanically and electrically with its supporting arm. The coil 18 is mounted on the L-shaped stylus arm 19 which is supported on the pivot 20 and which carries a stylus 21 for engaging the record. The vertical vibrations of the stylus when driven by a hill and dale record vibrate the coil in an annular airgap formed by the central pole piece 22 and the outer pole piece 23 and the currents generated in the coil are conducted to the terminals 17 over a circuit including the leads 24, 24 connecting block 25 and wires 26, 26.

The stylus arm is secured in position by a brass plate 27 and a brass member 28 which together house the rubber bearing 29 for the pivot 20. The member 28 is L-shaped and furcated as shown in Fig. 2 to extend forwardly on each side of the stylus arm to protect it from injury. When sufficient damping for the purpose of the invention can not be applied conveniently at the pivot of the moving system, any desired amount of additional damping may be applied in other ways as, for example, by means of a rubber pad 30 pressed by the cover plate 31 against the rod or wire 32 extending between the vertical and horizontal parts of the stylus arm.

In cases where the second resilient coupling is desirable it may take the form shown in Fig. 1 in which the frame 16 has a section of reduced stiffness consisting of a thin plate 33 and in which a rubber pad 34 is secured at either end to the stiffer portions of the frame. This damped flexible magnet supporting structure permits relative motion to occur at certain frequencies between the magnet structure and its supporting arm and therefore gives greater latitude in the choice of circuit constants to produce a given equalizing effect than in the structure already described in which the magnet and the arm vibrate as a unit over the whole frequency range.

When only the first resilient coupling is used the reproducer may be shown schematically as in Fig. 5 and diagrammatically as in Fig. 6 in which M is the effective mass in grams of the normally stationary structure of the reproducer and its pivoted supporting arm 35, m is the effective mass in grams of the moving system of the reproducer, S is the total effective stiffness in dynes per centimeter of the pivoted connection between the moving and stationary structures and R is the resistance in mechanical ohms of the rubber damping members, all of which are referred to the stylus point.

If V_1 is the velocity of the stylus tip and V_2 is the relative velocity of the elements generating the output electromotive force (in this case the coil 18 and the magnet 15) then

$$\frac{V_2}{V_1} = \frac{j\omega M}{R + j\omega M - j\frac{S}{\omega}} = \frac{1}{1 - \left(\frac{\omega_0}{\omega}\right)^2 - j\frac{R}{\omega M}}$$

where ω_0 is 2π times the resonant frequency as determined by the expression

$$\sqrt{\frac{S}{M}}$$

Since the reproducer is a moving coil device the output electromotive force is directly proportional to V_2 and the response is proportional to the magnitude of the complex quotient of

$$\frac{V_2}{V_1}$$

which varies with frequency in the manner shown by the curve of Fig. 7. The values R, S and M for

the reproducer are proportioned so that the increase in response is sufficient to correct approximately for the drooping recorder characteristic for frequencies above the resonant frequency f_0 which will ordinarily be between 50 and 100 cycles per second. Since rubber is both resilient and dissipative when subjected to a vibratory force, the rubber bearing 29 and the pad 30 (when used) will act both as stiffnesses and resistances in varying proportions depending upon the dimensions and the particular type of rubber or other material used. Alternatively the required resistance and stiffness may be obtained largely in separate elements such as the pad 30 for resistance and a non-dissipative biasing spring in place of the rubber bearing 29. In choosing the constants of the reproducer to obtain the desired equalization it must be remembered that the stylus point impedance (the ratio of the applied force to the resulting stylus velocity) should be kept as low as possible to minimize record wear.

Assuming a recorder characteristic as shown in Fig. 11 very good results are obtained by proportioning S and M so that f_0 is 70 cycles and proportioning R and M so that

$$\frac{R}{M} = 118.$$

With these constants the reproducer characteristic will be substantially as shown in Fig. 12 so that when the reproducer plays a record cut by the recorder of Fig. 11 the reproducer output will be in substantial accordance with the original sounds for frequencies down to nearly 60 cycles. The rubber members 29 and 30 can be most readily proportioned by experiment. If with the structure first tried the resonant frequency f_0 is too high the stiffness should be reduced, as for example, by increasing the thickness of the rubber bearing or increasing the unsupported length of the pad 30. If the resonance curve is too flat to effect proper compensation the mechanical resistance should be reduced by using a less dissipative material.

A reproducer with two resilient couplings is similarly illustrated in Figs. 8 and 9 in which L_1 , L_3 and L_4 are the effective masses in grams respectively of the moving system, the reproducer structure and the reproducer arm, S_2 and S_3 are the effective stiffnesses in dynes per centimeter of the pivoted connection and the plate 33, and R_2 and R_3 are the resistances in mechanical ohms of the rubber damping in the moving system and the rubber pad 34. For this reproducer as shown in Fig. 9 the velocity ratio may be shown to be

$$\frac{V_2}{V_1} = \frac{j\omega L_4 + \frac{(R_3 - j\frac{S_3}{\omega})j\omega L_4}{R_3 - j\frac{S_3}{\omega} + j\omega L_4}}{R_2 - j\frac{S_2}{\omega} + j\omega L_4 + \frac{(R_3 - j\frac{S_3}{\omega})j\omega L_4}{R_3 - j\frac{S_3}{\omega} + j\omega L_4}}$$

The variations of the magnitude of this ratio with frequency are shown in Fig. 10. From the shape of this curve it will be apparent that the reproducer will equalize for the droop in the recorder characteristic only for frequencies above f' so that the circuit constants must be so chosen that f' occurs at the lower limiting frequency of the range of interest. One reproducer of this type has the following constants: $S_2 = 3.5 \times 10^6$, $R_2 = 1000$, $L_2 = 20$ grams, $S_3 = 5 \times 10^6$, $R_3 = 1000$, and L_4 is 200 grams. Such a reproducer will

equalize for the recorder characteristics for frequencies down to about 70 cycles.

While the invention has been described with particular reference to hill and dale reproducers it will be obvious that the same general principles will apply in the design of lateral type reproducers for the same purpose. The hill and dale reproducer shown in the drawings can be readily converted to a lateral type having the same equalizing characteristic by cutting away one of the furcations of the member 28 and inserting a suitable stylus in the side of the stylus arm instead of in the bottom of the arm as shown.

It will also be understood that the general principles of the design are equally applicable to other mechanically driven vibratory devices in which low frequency equalization is required. Various structural modifications will readily suggest themselves 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 vibration translating device, a normally stationary structure including a magnet system having an air-gap, a generating element in the gap, means for vibrating the element, and a damped resilient connection between the stationary structure and the element having its stiffness and damping correlated to the mass of said structure so that said structure vibrates out-of-phase with the element over a portion of the low frequency range.

2. In combination, a vibration translating device comprising a magnet system, a generating element cooperating therewith, means for driving the element and a damped resilient connection between the element and the magnet system, means for supporting the device, and a second damped resilient connection between the device and its supporting means.

3. In combination, a phonograph record in which the low sound frequencies are recorded at less than their proper relative amplitudes with respect to the high frequencies, and a reproducer for reproducing said record with said frequencies in proper amplitude relation comprising a magnet system, a generating element in operative relation thereto, means for driving the element, and

means for mounting the element on the magnet system, said mounting means having such values of stiffness and mechanical resistance that the reaction of the vibrations of the element on the mounting at said low frequencies vibrates the magnet system out-of-phase with its own vibration to produce a reproducer output having the frequency amplitude relation of the original sounds.

4. A phonograph reproducer for reproducing records in which the high frequencies are recorded at constant velocity and the low frequencies at constant amplitude, comprising a normally stationary structure including a magnet system, a generating element in operative relation to the magnet system, a stylus for driving the element, and a damped resilient connection between the element and the structure, the stiffness of said connection being correlated to the mass of the structure to cause the reproducer to resonate at a frequency of less than 100 cycles per second.

5. A phonograph reproducer for reproducing records in which the high frequencies are recorded at constant velocity and the low frequencies at constant amplitude, comprising a normally stationary structure including a magnet, a moving system including a generating element in operative relation to the magnet, and a stylus for driving the element, a resilient connection between the moving system and the stationary structure having its stiffness correlated to the mass of the structure to resonate at less than 100 cycles per second, and means for damping the system to compensate for the frequency amplitude characteristics of the record down to the resonant frequency.

6. A phonograph reproducer having a substantially flat response characteristic for frequencies above 300 cycles per second and a progressively increasing response for a portion of the lower frequency range comprising a magnet, a moving system including a generating element in operative relation to the magnet, and a stylus for driving the element, and a damped resilient connection between the magnet and the system having such a stiffness that the reproducer resonates below 100 cycles per second.

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