

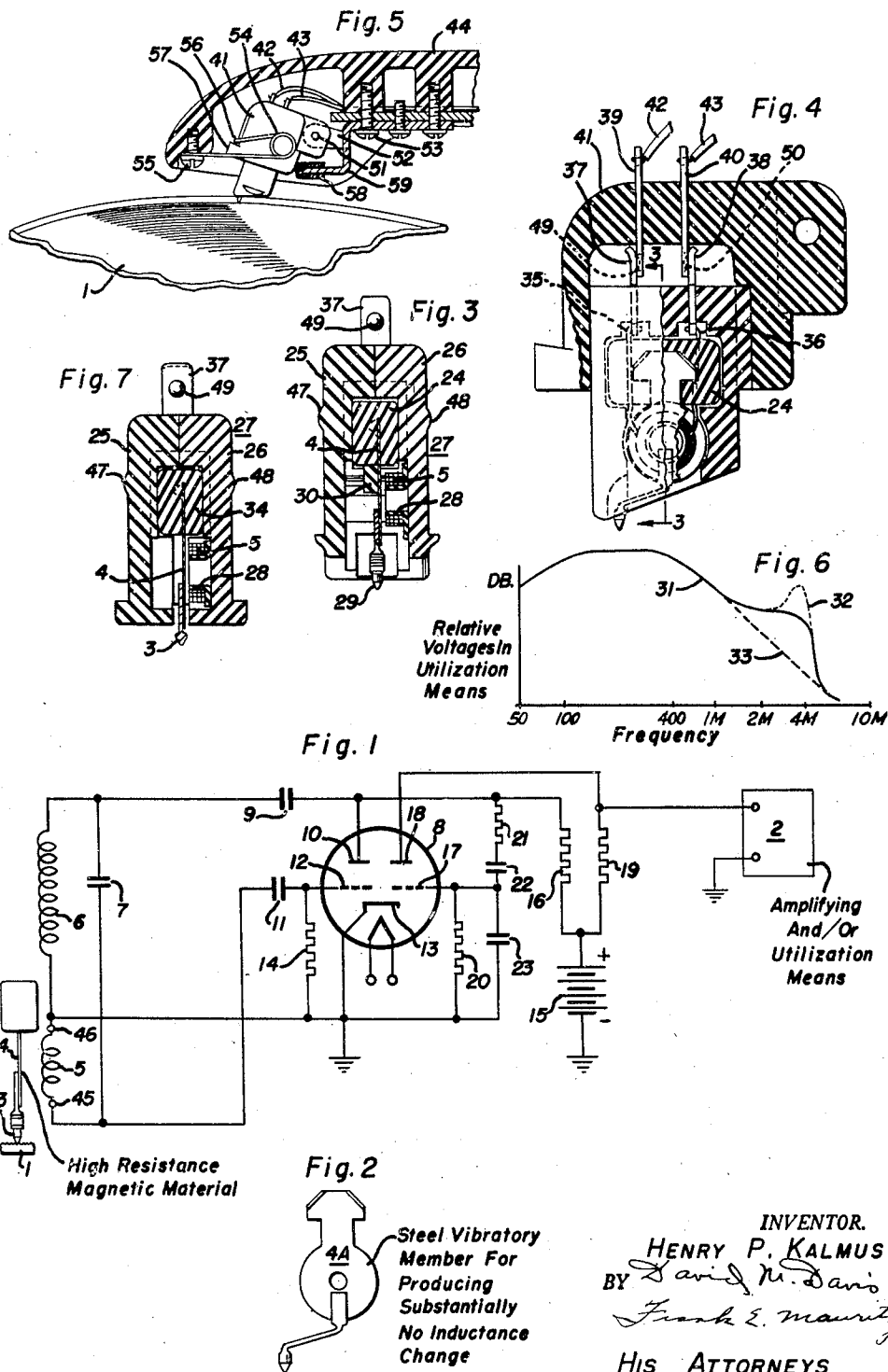
Nov. 29, 1949

H. P. KALMUS
MODULATED-OSCILLATOR TYPE SIGNAL
TRANSLATING APPARATUS

2,489,379

Filed April 13, 1946

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

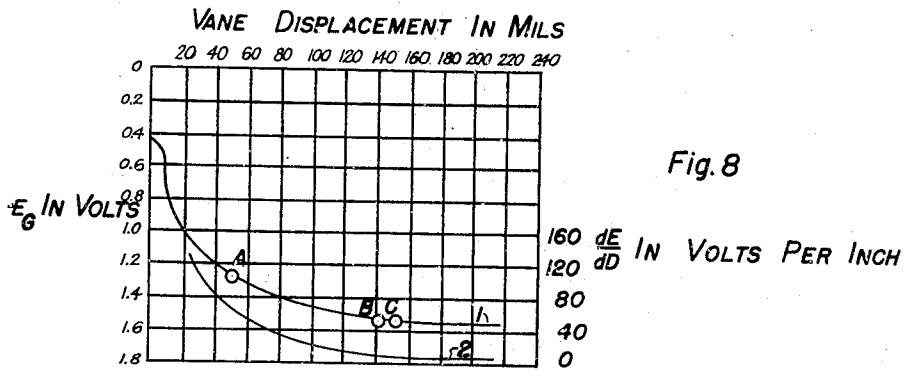


Fig. 8

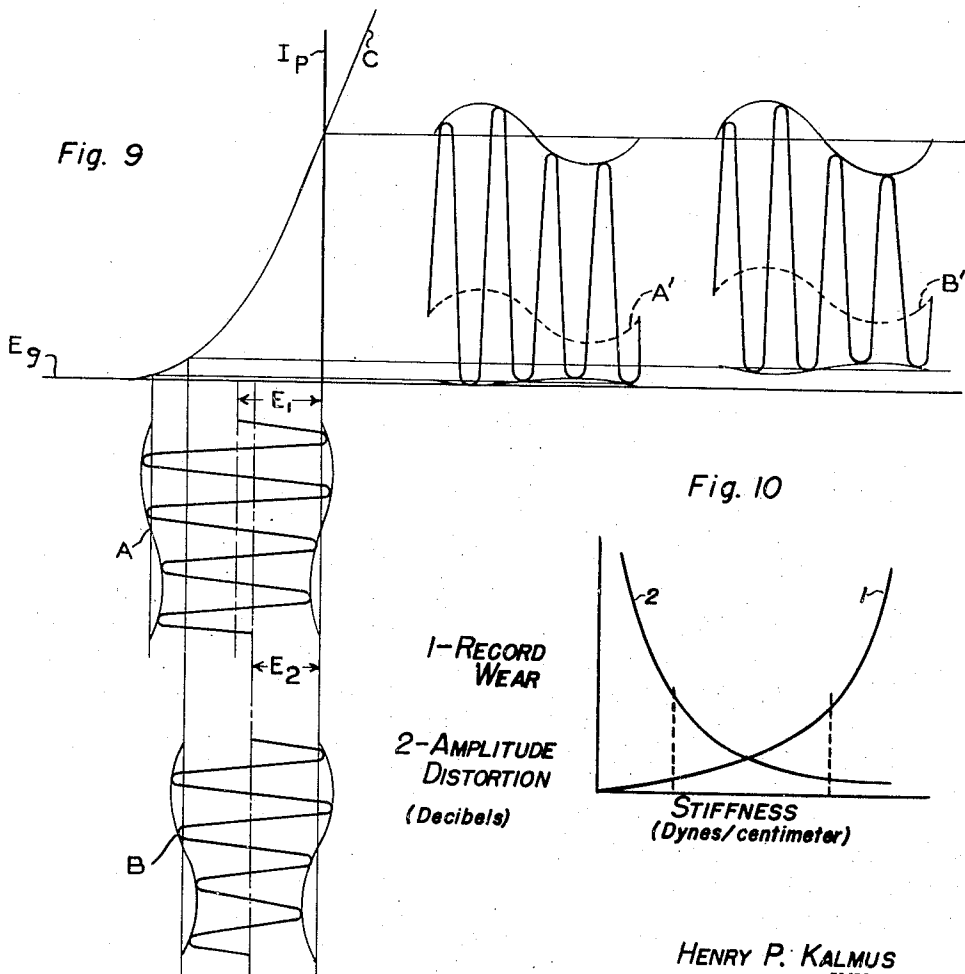


Fig. 10

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3 Sheets-Sheet 3

Fig. 11

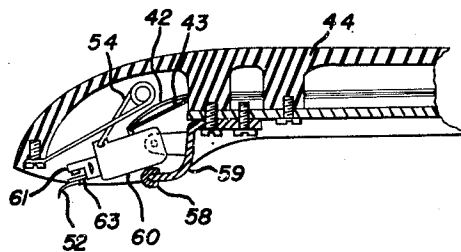
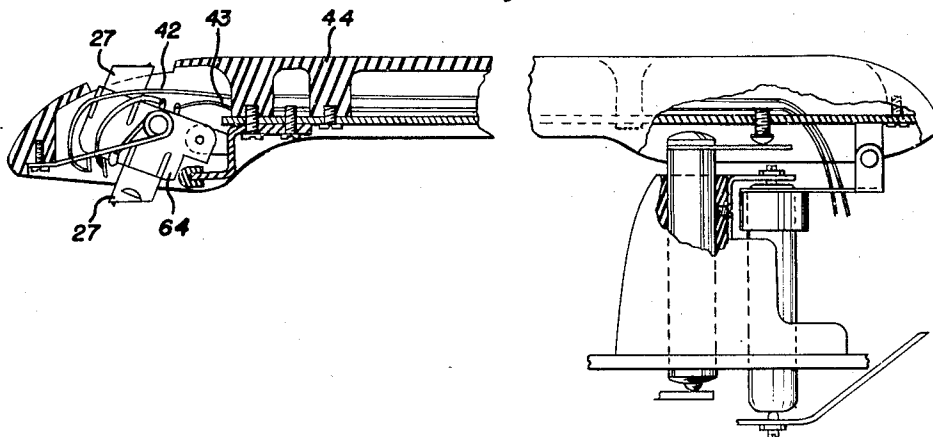


Fig. 12



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UNITED STATES PATENT OFFICE

2,489,379

MODULATED-OSCILLATOR TYPE SIGNAL
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Application April 13, 1946, Serial No. 662,044

7 Claims. (Cl. 179-100.4)

1

The present invention pertains to signal translating apparatus of the type in which vibrations of a member at audio frequencies produce corresponding variations in current in an associated electrical circuit. The invention relates more especially to such arrangements as phonograph pickup devices and associated apparatus in which vibrations of a member produce amplitude modulation of a high frequency wave.

In my co-pending application, Serial No. 585,826; filed March 31, 1945; and assigned to the same assignee as the present application; there is disclosed a novel type of phonograph transducer, or pickup, wherein a member is vibrated in accordance with the undulations of a sound track on a movable record medium to vary at least one electrical characteristic of a winding associated with the member to produce corresponding variations in the amplitude of oscillations generated in a tuned circuit including said winding.

It is an object of the present invention to provide an improved signal translating apparatus of the above type wherein an optimum relation is obtained between the compliance of the vibratory member and the inertia of the supporting means, or tone arm, to produce a minimum amount of record wear consistent with reasonably small amplitude distortion of the modulated oscillations.

A further object of the present invention is to provide an improved form of electrical circuit for generating oscillations and for demodulating the modulated oscillations produced by the pickup, which circuit is arranged to provide a much higher output than the corresponding circuit disclosed in my prior application whereby a higher signal to noise ratio is obtained.

A still further object of the present invention is to provide an improved electrical circuit, in accordance with the preceding object, which is arranged to operate in a non-linear manner complementary to an inherent non-linear characteristic of the modulating means whereby residual amplitude distortion produced by eccentricity or warpage of the record medium is substantially reduced.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with accompanying drawings in which:

Figure 1 illustrates a preferred form of system embodying certain features of the invention,

Figure 2 illustrates a vibratory member par-

2

ticularly useful in the arrangement of Figure 1,

Figures 3 to 5 illustrate details of a phonograph pickup construction particularly useful in the arrangement of Figure 1, Figure 3 being a section taken substantially on line 3-3 of Figure 4,

Figure 6 illustrates certain frequency response characteristics obtained with the use of the apparatus described herein,

Figure 7 illustrates a modified pickup structure for use in the arrangement of Figure 1, the structure of Figure 7 being a modification of the embodiment of Figure 3.

Figure 8 is a graph illustrating certain characteristics of the pickup structure described herein,

Figure 9 is a graph illustrating the operation of the electrical circuit disclosed in Figure 1,

Figure 10 is a graph illustrating the effects of varying the stiffness, or compliance, of the vibratory member of the transducer,

Figure 11 illustrates a modified pickup structure for use with vertically cut records, and

Figure 12 illustrates a modified pickup structure for use in a record changer adapted to play both sides of the records automatically.

The apparatus described herein, set forth by way of example of one kind of apparatus which may embody the present invention, is arranged as shown in Figure 1 to transform intelligence recorded on a movable record medium 1 into suitable current variations of audible frequency in a utilization or amplifying device 2.

The intelligence on record 1 is in the form of laterally cut impressions of undulating character in which a suitable stylus 3 travels as the record 1 is rotated by conventional means, whereby a vibratory member 4 attached to the stylus is vibrated to produce corresponding changes in at least one electrical characteristic of an inductance element or coil 5, which is coupled to the vibratory member.

Inductance element 5, whose effective resistance or inductance value may be cyclically altered by corresponding movement of stylus 3, constitutes one element of a single tuned circuit 5, 6, 7, in an oscillatory circuit including discharge device 8, which is shown in Figure 1 as a twin triode. The first triode section of discharge device 8 with its associated circuits functions not only as an oscillation generator but also as a demodulator or detector.

The circuit formed by the serially connected inductances 5 and 6 is connected in parallel with a condenser 7 to form the frequency determining circuit 5, 6, 7. One terminal of the tuned circuit is connected through condenser 9 to the anode 10 of the first triode section of device 8. The other terminal of the tuned circuit is connected through condenser 11 to the control grid or electrode 12 of the first triode section of device 8. The junction

3

tion point of inductance elements 5 and 6 is connected to the common grounded cathode 13. Grid-leak resistance 14 connected between grid 12 and cathode 13 serves to impress a suitable biasing potential on the control grid 12. Space current for anode 10 is supplied from voltage source 15 which has its positive terminal connected through resistance 16 to anode 10 and its negative terminal connected to the grounded cathode 13.

The operation of the electrical circuit thus far described in connection with Figure 1 is as follows. Device 8, including anode 10, control electrode 12 and cathode 13, produces a sustained oscillatory current of constant amplitude in the tuned circuit 5, 6 and 7 in well known fashion when the vibratory member 4 does not move. Movement of vibratory member 4, for example, by stylus 3 traveling in a conventional phonograph record sound track, produces cyclical changes in the impedance of inductance element 5 to change the amplitude of the oscillatory current flowing in the tuned circuit 5, 6, and 7, whereby amplitude modulation of such oscillatory current is produced. The values of condenser 11 and grid-leak resistor 14 are chosen so that the bias voltage developed thereacross causes device 10, 12, 13 to function as a plate-bend detector to demodulate the amplitude modulated oscillations impressed between control grid 12 and cathode 13. The modulation components resulting from such plate-bend detection appear across load resistance 16 in the anode circuit of device 10, 12, 13. One important feature of the present invention, to be more fully described hereinafter, is that the device 10, 12, 13 serves to produce oscillations which are modulated in accordance with the sound track undulations on the phonograph record and simultaneously to demodulate the modulated oscillations in a non-linear manner which is complementary to a non-linear characteristic of the transducer, whereby distortion produced by the transducer is balanced out of the audio frequency signals developed in the anode circuit of device 10, 12, 13.

Anode 18 is supplied with operating potential from the positive terminal of source 15 through resistance 19. The control grid 17 is maintained at a suitable continuous potential with respect to cathode 13 by connecting resistance 20 therebetween. The modulation components appearing at anode 10 are transferred to the control grid-cathode circuit of device 18, 17, 13 through the series circuit comprising filter resistance 21, isolating and coupling condenser 22 and filter condenser 23, grid 17 being connected to the junction point of condensers 22 and 23 and the other terminal of condenser 23 being grounded. Filter condenser 23 has a relatively small reactance at the frequency of oscillation of device 10, 12, 13 so that substantially all of the amplified voltage appearing at anode 18 is of a frequency corresponding to the frequency of vibration of the vibratory member 4. The amplified voltage is applied to device 2.

The vibratory member 4 of Figure 1, which is coupled to coil 5, is preferably of high resistance material and in one form of the present invention is .004" thick stainless steel known in the trade as American Iron and Steel Institute Type No. 302. Stainless steel Type 302 contains about 18% chromium, about 8 or 9% nickel, about 0.08 to 0.2% carbon, traces of manganese, silicon, phosphorus, sulphur and copper and the remainder iron. Stainless steel Type 302 is pre-

4

ferred because it is substantially non-magnetic whereby a minimum amount of 120 cycle hum is introduced into the pickup from nearby motors, transformers, etc. It has been found that stray 60 cycle fields shift the working point on the magnetization curve of the vibratory member, when it is made of magnetic material, with the result that the inductance and effective resistance of the coil 5 coupled thereto change. Such changes produce amplitude modulation of the oscillating current. For these reasons, where stray alternating magnetic fields are present, the material preferably possesses high resistance and low permeability. When such material is used the desired modulation is produced substantially entirely by eddy current loss in the high resistance material, and the modulation is substantially unaffected by variations of permeability of member 4 in the presence of such stray fields.

Vibration of a member of such material in the vicinity of inductance element 5 causes amplitude modulation of the oscillatory current because (1) the quality factor or Q of the inductance element is changed cyclically and (2) the amount of feedback voltage from the anode 10 to grid 12 is changed cyclically due to cyclical changes in the inductance of element 5. The inductance of coil 5 is preferably less than the inductance of coil 6 so that when the impedance of coil 5 is altered the feedback factor is altered in such a way that amplitude modulation produced by inductance change is in phase with the amplitude modulation produced by the change in Q, the quality factor.

Viewed in another way, the inductances 5 and 6 and condenser 7 form a pi network through which oscillation voltage is transferred from anode 10 to control electrode 12. In usual forms of electron discharge oscillation generators, and in the type illustrated in Figure 1, there need be only a part of the voltage on the anode fed back to the control electrode, and, to maintain the generator in operation, that voltage so fed back must be maintained within certain limits. That is, if the amount of voltage fed back to the control electrode is too little, the generator ceases the production of oscillations. The pi network 5, 6, 7 is effective to alter in substantial degree the amount of voltage fed back from anode 10 to control electrode 12 as the impedance of inductance 5 changes.

In the fundamental form of the present invention, member 4 is conductive. To make it magnetic as well as conductive is useful when it is desired to reduce or eliminate inductance change of coil 5 and corresponding change of oscillation frequency. Also, to make member 4 magnetic introduces hysteresis loss which aids the eddy current effect in member 4 to change the effective resistance of coil 5 and consequent change of oscillation intensity. Cyclical changes in the inductance of element 5 cause a certain amount of frequency modulation of the generated wave in tuned circuit 5, 6, 7, but substantially only those components which produce amplitude modulation are detected in device 10, 12, 13.

When the movable element 4 is constructed of magnetic and conductive material, movement of such element closer to coil 5 has a twofold effect on the inductance of that coil. Since element 4 has a greater permeability than that of air the inductance tends to increase; moreover since element 4 is also conductive, the inductance tends to decrease. The net change in the inductance

5

of coil 5 is equal to the difference between these two opposing tendencies. At the same time, as element 4 approaches the coil both the increased hysteresis loss and the increased eddy current loss operate to decrease the damping resistance reflected in coil 5. In one arrangement incorporating an embodiment of the present invention, the permeability and specific resistance of element 4A (Figure 2) are so proportioned that substantially no net inductance change results from movement of the element with respect to the coil. Thus amplitude modulation of the oscillations generated in the tuned circuit 5, 6, 7 is effected with substantially no accompanying frequency modulation.

Figures 3-5 show a preferred construction for mounting the vibratory member having the general reference numeral 4. In Figures 3-5 the vibratory member is of the stainless steel type previously mentioned, for reducing to a minimum the amount of extraneous 120 cycle hum introduced into the system, and is of a thickness of approximately .004". The upper end thereof is embedded in a hard plastic base 24 which in turn is clamped between two halves 25, 26 of a plastic casing 27, the two halves being held together by cement or the like or by bonding with heat and pressure. Inductance coil 5 is mounted on coil form 28 which is fastened, for example by cement or the like, to the inside face of casing half 26, in close proximity to member 4 with circular coil form 28 and circularly shaped member 4 substantially coaxial.

The free end of vibratory member 4 has a resilient L-shaped record contact stylus or needle 29 affixed thereon, for example by spot welding or the like, to give a desirable vertical compliance for the purpose of reducing needle chatter and record wear, and for producing a desirable response curve which is substantially flat between 2000 and 4000 cycles per second with a sharp cutoff after 4000 cycles per second.

The phonograph pickup arrangement of Figures 3-5 incorporated in Figure 1 preferably has a frequency response characteristic of the type shown in Figure 6, wherein output voltage in the utilization device 2 is plotted as ordinate and frequency of the corresponding voltages is plotted as abscissa. The sharp cutoff after 4000 cycles is due mainly to the fact that the vibratory member 4 in Figures 3-5 is inherently mechanically resonant in its second mode at a frequency between 3000 and 4000 cycles per second. At this frequency the mode of vibration is such that the ends of the vibratory member tend to remain stationary and the middle portion adjacent the inductance element 5 vibrates with relatively large amplitude. In order that the amplitude of vibration at the resonant frequency be not too large a damping element 30, such as a block of plasticized cellulose nitrate, is fixed, as by heat and pressure, on the vibratory member at the upper end thereon in abutting relationship with the bottom surface of the base member 24. This plastic material is preferred over ordinary rubber since it possesses more internal friction than rubber. Without the presence of a damping element 30 the characteristic curve 31 in full line in Figure 6 is peaked in the manner indicated by the dotted line portion 32 thereof, but with a suitably proportioned vibratory member 4 and damping element 30 the characteristic curve 31 is substantially flat in the range of 2000 to 4000 cycles per second. Without resonant effects in the mechanical vibratory member 4

6

the characteristic curve is substantially as indicated by the dotted line 33.

In another form of the invention, shown in Figure 7, the stylus or record engaging portion 3 at the end of vibratory member 4 may be straight instead of L-shaped as shown in the preferred embodiment of Figure 2. Furthermore, instead of the upper end of the vibratory member 4 being embedded in a hard plastic base 24, as shown in the preferred embodiment in Figure 4, the upper end of member 4 may be embedded in an elastic base 34 such as rubber. In such case the elastic body 34 is held between the two halves 25, 26 of casing 27 in the same manner as is shown in Figure 3.

Inductance coil 5 has its terminals 35, 36 permanently connected to metallic contact elements 37, 38, respectively, which are embedded in and extend from the inside to the outside of casing 27, the outer ends of contact elements 37, 38 being adapted to make good electrical and mechanical contact with corresponding contact elements 39, 40 embedded in and extending through the casing holder 41. Conductors 42, 43, which are permanently fastened to the upper ends of contact elements 39, 40, respectively, extend through at least part of the tone arm 44 to the appropriate terminals 45, 46 in the oscillator circuit of Figure 1.

The replaceable casing 27, which may be separately sold as an article of commerce, contains in a unitary structure the vibratory member 4 and coil 5 coupled thereto in predetermined spaced relationship, which unitary structure is held snugly in the casing holder 41 by projections 47, 48 engaging correspondingly shaped depressions (not shown) in the walls of casing holder 41 and by contact projections 49, 50 engaging correspondingly shaped depressions in contact elements 39, 40.

The casing holder 41 is pivotally mounted about the axis of fixed pin 51 in a pair of arms 52 disposed on opposite sides of the casing holder 41, each arm having one end thereof fastened to the tone arm, for example by screw 53, and the other end thereof circularly formed to provide a bearing member with pin 51. Arms 52 may be flexible but are preferably non-flexible. The casing holder 41 is normally spring biased downwardly for rotation about the axis of pivot pin 51 by coil spring 54 having its ends fastened to tone arm 44, for example by screw 55, and having an intermediate portion 56 engaging a shoulder 57 on the holder 41 to press the holder downwardly in the direction of counterclockwise rotation about pin 51. The coil spring 54 is made sufficiently flexible to protect the pickup unit against injury in case the tone arm is dropped on a record. In such case the pickup unit including the casing holder 41 is deflected upwardly against the action of weak spring 54 and a piece of felt 58 on the free end of arm 59 engages the casing holder 41, arm 59 being fastened to the tone arm, for example by screw 53, to serve as a stop for limiting the movement of casing holder 41; the heel of the replaceable casing 27 is brought to bear on the surface of the record disc and the stylus 3 is retracted. Protection is also afforded to the L-shaped stylus by extending the casing halves 25, 26 sufficiently far downwardly so that, when more than a predetermined force is applied to the stylus, it moves upwardly within the space defined by the casing halves 25, 26. Since the ends of arms 52 and 59 are both held by the same screw 53, it is obvious that the arm 52 may

form an integral extension of arm 59. The tone arm 44 is pivotally secured at one end in any suitable manner, for example as illustrated in Figure 12 and fully described in the co-pending application of Ralph A. Mullaney et al.; Serial No. 649,146; filed February 21, 1946, and assigned to the same assignee as the present invention.

The oscillator detector arrangement shown in Figure 1 is identical to that shown in my prior application except for the values of condenser 11 and resistor 14. In the present case these components have values which result in an entirely different manner of operation than that described in my prior application. In my prior application both grid detection and plate-bend detection took place in device 10, 12, 13. As these two types of detection act differentially in the anode circuit, the output which can be obtained is limited. It has been found that if the values of condenser 11 and resistor 14 are properly chosen, so as to prevent the bias voltage impressed on grid 12 from fluctuating substantially at an audio frequency rate, no grid detection occurs. A much larger audio frequency signal is then developed in the anode circuit of device 10, 12, 13 resulting in a greatly improved ratio between the desired signal and tube noise due to thermal agitation effects. It has also been found that if the values of condenser 11 and resistor 14 are properly chosen, so as to enable the bias voltage impressed on grid 12 to fluctuate at a rate corresponding to the rotational speed of the record disc 1, the amplitude distortion of the modulated oscillations due to eccentricity of the record disc may be balanced out through variation of the detecting efficiency in a manner complementary to the non-linear characteristic of the modulator and transducer.

In other words, in accordance with this invention, a resistance-capacitance biasing network is used to bias device 10, 12, 13 to a region of relatively high curvature of its anode characteristic to cause the device to operate as a plate-bend detector for amplitude modulation at audio frequency rates. The biasing network, comprising condenser 11 and resistor 14, has a time constant long for audio frequencies but short for sub-audio frequencies to provide a bias potential, within the non-linear portion of the anode characteristic, which varies substantially only in response to sub-audio frequency amplitude modulation of the oscillatory current in circuit 5, 6, 7. In this way the detection efficiency of the plate-bend detector is varied in such manner as automatically to compensate for undesired slow changes in oscillation amplitude due to slow variation in the mean position of the vibratory member 4 which may result, for example, from eccentricity or warpage of the record disc.

It is preferred to construct the transducer and tone arm so as to result in a minimum of record wear consistent with low distortion of the modulated oscillations and to eliminate the residual distortion in the detector. Quite often in commercial records the hole, or the sound track, is not accurately centered, and the tone arm head is driven back and forth in a radial direction during each revolution of the record disc. Due to the inertia of the arm, the mean position of the stylus then varies at a frequency of 1.3 cycles per second, corresponding to 78 revolutions per minute of the record disc. The deflection due to this motion is superimposed upon the deflection due to undulations in the sound track on the record disc. In pickups with large linear ranges

(e. g. crystal or dynamic systems) eccentricity produces neither distortion nor amplitude changes. In electronic pickups, having only a limited linear range, eccentricity results in cyclical variations in amplitude which may be considered as amplitude distortion.

If the mass of the tone arm is small and the moving element has a low compliance, or in other words is stiff, the arm follows the stylus tip and the vane is not deformed and displaced relative to the tone arm. In this case eccentricity does not produce any amplitude change but the record wear is considerable due to the large forces between the stylus and the sides of the record grooves necessary to overcome the inertia of the tone arm. If the mass of the tone arm is large and the moving element has a high value of compliance, the arm does not follow the needle tip and the vane is greatly deformed and displaced relative to the tone arm. In this case the record wear is reduced to a minimum but the distortion due to non-linearity of the pickup is high.

The present invention provides a phonograph pickup in which the compliance of the vibratory member is made large, in order to minimize record wear and needle talk; the amplitude distortion due to non-linearity of the pickup is substantially compensated in the plate-bend detector by corresponding variation of the detection efficiency, as explained above.

The effect of varying the stiffness of the vibratory member and stylus of the transducer is illustrated by curves 1 and 2 in Figure 10 in which the ordinates are drawn to a logarithmic decibel scale and the abscissae are drawn to a linear scale. Curve 1 shows record wear as ordinate plotted against stiffness as abscissa. The record wear is inappreciable if the stiffness is lower than the value corresponding to the knee of the curve. If the stiffness is lowered too far the amplitude distortion due to record eccentricity becomes appreciable. Curve 2 shows such amplitude distortion as ordinate plotted against stiffness as abscissa. The position of the knee of this curve depends on the tone arm inertia, which should be low enough to make the knee of curve 2 occur at a lower value of stiffness than the knee of curve 1. At any value of stiffness between the knees of these two curves, which knees are indicated by the dotted abscissae, an optimum relation between record wear and amplitude distortion exists. The compliance of the vibratory member and stylus of the transducer described herein is preferably made in the order of 9.6×10^{-6} centimeters per dyne, corresponding to a stiffness well below the knee of curve 1. The compliance is measured at the tip of the stylus in the direction of movement thereof by the undulations in the sound track. With a tone arm inertia of 20 grams the knee of curve 2 is located below the value of stiffness corresponding to a compliance of 9.6×10^{-6} centimeters per dyne.

Let the tone arm inertia or mass, assumed to be concentrated at the end of the arm, be represented by M , and let the compliance of the vane be represented by C_m . When the groove displacement at the needle tip due to eccentricity of the record is x_1 , and x_2 is the deviation of the vane from its rest position, then

$$x_2 = x_1 \frac{w^2 M C_m}{w^2 M C_m - 1} \\ = -x_1 \frac{(2\pi f)^2 M C_m}{1 - (2\pi f)^2 M C_m}$$

where f is the frequency corresponding to the rotational speed of the record disc.

Using a value of C_m of 9.6×10^{-6} centimeters per dyne, determined by curves 1 and 2 of Figure 10 as described above, assuming a mass M of 20 grams and an eccentricity of $\frac{1}{16}$ ", and also assuming that $f=1.3$ c. p. s., we obtain 0.8 mil for x_2 by substitution in the above equation.

Figure 8 is a graphical representation of the vane displacement characteristics of a large scale model of a pickup constructed in accordance with the present invention, the linear dimensions of the model being larger than those of a normal size pickup by a factor of 10. The characteristics for a normal size pickup are similar, if the abscissae are corrected by a factor of

$$\frac{1}{10}$$

Curve 1 represents the relationship between the oscillation amplitude and the displacement or distance between the vane and its associated coil; point A corresponds to the minimum gap width and points B and C correspond to the limits of the normal working range in the absence of record disc eccentricity. The normal working range covers 10 mils in the large scale model, or 1 mil in the actual pickup.

In the absence of record disc eccentricity, the average vane displacement is constant (at a value midway between points B and C). If it is first assumed, for purposes of analysis, that the detection is linear, the audio output is proportional to the slope of curve 1 at the operating point. Curve 2 represents the first derivative of curve 1 and is indicative of that slope; thus curve 2 is representative of the pickup sensitivity at any given average gap width.

The normal vane displacement in the actual pickup is approximately 12 mils. In this region the slope of curve 2 in Figure 8 is equivalent to an amplitude change of 0.5 db per mil. When the stylus deflection due to eccentricity is 0.8 mil, the resulting variation in amplitude is 0.4 db. This change is small enough so as not to be particularly objectionable and yet the compliance of the moving vane is so high as to result in very little record wear and also very little noise radiation from the pickup and record. If now, the plate-bend detection arrangement of the present invention is substituted for the linear detection arrangement assumed above, even the small remaining amplitude distortion may be eliminated. As the average displacement of the vane decreases the average amplitude of the oscillations produced by device 10, 12, 13 also decreases, thereby causing the peak value of the alternating voltage appearing between the grid 12 and cathode 13 to decrease. Fluctuations in the average gap width may be caused by eccentricity of the record disc and may occur at a frequency of 1.3 c. p. s. when the record disc rotates at 78 R. P. M. When the values of resistor 14 and condenser 11 are chosen so as to have a time constant which will permit the bias voltage impressed on the grid 12 to vary with the slow fluctuations in the magnitude of the high frequency oscillations, but to prevent fluctuations in the bias voltage at an audio frequency rate, the distortion can be eliminated from the demodulated signals developed in the anode circuit of the detector, as has been illustrated in Figure 9.

In Figure 9, curves A and B represent the voltages impressed on the grid 12 when the tone-arm is swinging away from and towards, respec-

tively, the center of the record disc. When the tone-arm is swinging away from the center of the record disc the mean value of the gap between the vane and the associated coil increases, resulting in a high oscillation voltage amplitude on the grid 12. Conversely, when the tone-arm is swinging towards the center of the record disc the average displacement between the vane and the associated coil decreases, resulting in a smaller oscillation voltage amplitude on the grid 12. Due to the change in the average value of the high frequency voltage impressed on the grid 12, the bias voltage impressed thereon varies from E_1 to E_2 thereby causing the detecting action to take place over a different portion of the plate characteristic curve C of the detector. The action of the plate-bend detector in compensating for slow changes in average vane displacement may be explained as follows. For a large average vane displacement, the oscillation voltage amplitude is high and the modulation depth for a given vane vibration amplitude is small. With a large oscillation voltage amplitude, the bias adjusts itself to an operating point whereat the curvature of the anode characteristic C is high, and at the same time the peak to peak swing of the control grid voltage extends over a large portion of that characteristic; consequently the detection efficiency is high.

Now, if the average vane displacement is decreased, the oscillation voltage amplitude decreases due to the loading effect of the vane on the tuned circuit 5, 6, 7 (Figure 1) but the modulation depth for a given vane vibration amplitude increases. The decreased oscillation voltage amplitude results in a decrease in the negative bias on grid 12, and the device 10, 12 13 (Figure 1) is biased to a region of slighter curvature of the anode characteristic C, and the peak to peak swing of the control grid voltage extends over a narrower portion of that characteristic; therefore the detection efficiency is decreased. By proper design of the circuit the resulting audio-frequency signals, represented by the dotted curves A' and B', in the anode circuit can be made equal in magnitude. It has been found that a substantially perfect balance can be obtained when tube 8 is a Type 7F7, resistor 14 is .15 megohm, condenser 11 is 200,000 micromicrofarads, and the normal value of the high frequency voltage impressed on the grid 12 is in the order of 1.8 volts.

Although the pickup construction thus far described is intended for use with laterally cut records, the same considerations apply to records of the vertically cut type. When vertically cut records are employed eccentricity produces no ill effects, but warpage of the record disc results in vertical displacement of the tone-arm which causes deviations in the mean position of the moving vane due to the force necessary to overcome the inertia of the tone-arm. A pickup structure suitable for use with vertically cut records has been illustrated in Figure 11. The construction of the arm 44 is identical to that shown in Figure 5, but the transducer 61 is mounted in the tone arm with the moving vane 63 lying in a plane which is substantially parallel to the plane of the record disc. The coil spring 54 biases a casing holder 60 against the felt tipped arm 59. The tension of this spring is just sufficient to maintain the casing holder 60 in contact with the felt tipped arm 59 during normal operation of the apparatus, but is sufficiently weak so that a sudden jar, such as that

produced by dropping the tone-arm on a record, allows the casing holder 60 to be deflected upwardly to prevent damage to the moving vane of the transducer 61, which is constructed similarly to the transducer 27 disclosed in Figures 3, 4 and 7 and is removably secured in the casing holder 60. The transducer 61 differs from that previously described principally in the fact that stylus 62 is formed perpendicular to the plane of the moving vane 63 to adapt the transducer for use with vertically cut records. The winding of transducer 61 is connected to terminals 45 and 46 of the circuit of Figure 1 by conductors 42 and 43.

The modified form of pickup disclosed in Figure 12 is similar to that disclosed in Figure 5 except that there is provided a casing holder 54, adapted to receive a pair of transducers 27, each identical to that disclosed in Figures 3, 4 and 7. An opening is provided in the top of the tone-arm 44 through which one of the transducers 27 projects to enable it to engage the under side of a record disc in the manner illustrated in the aforementioned copending application of Ralph A. Mul-laney et al. The windings of the two transducers are connected in series, as illustrated, or in parallel to terminals 45 and 46 of the circuit of Figure 1 by conductors 42 and 43 in the same manner as for a single transducer.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. Signal translating apparatus comprising: an oscillating plate-bend detector having an oscillation generator portion for producing oscillations of superaudible frequency and including an electron discharge device having a grid voltage-anode current characteristic which is non-linear throughout a predetermined range of grid potentials; a transducer having a modulating element coupled to said generator portion to amplitude modulate said oscillations in response to relative movement of said element and a component of said generator portion; a biasing network for said device included in said oscillating detector and comprising a resistor and a condenser having a time constant long for audio frequencies and short for sub-audio frequencies to provide a grid bias potential within said range which varies substantially only in response to sub-audio frequency amplitude modulation of said oscillations; and an anode load impedance for said device for deriving audio-frequency modulation components of said modulated oscillations.

2. Signal translating apparatus comprising: an oscillation generator and plate-bend detector system in which the generator portion produces oscillations of superaudible frequency, said system including a frequency determining circuit for determining the frequency of said oscillations and further including an electron discharge device having a grid voltage-anode current characteristic which is non-linear throughout a predetermined range of grid potentials; a transducer having a modulating element coupled to said circuit to amplitude modulate said oscillations in response to relative movement of said element and said circuit; a biasing network for said de-

vice included in said generator detector system and comprising a resistor and a condenser having a time constant long for audio frequencies and short for sub-audio frequencies to provide a grid bias potential within said range which varies substantially only in response to sub-audio frequency amplitude modulation of said oscillations; and an anode load impedance for said device for deriving audio-frequency modulation components of said modulated oscillations.

3. Signal translating apparatus comprising: an oscillating plate-bend detector having an oscillation generator portion for producing oscillations of superaudible frequency, said oscillating detector including a frequency determining circuit, comprising an inductance coil, for determining the frequency of said oscillations and further including an electron discharge device having a grid voltage-anode current characteristic which is non-linear throughout a predetermined range of grid potentials; a transducer having a movable conductive element inductively coupled to said coil to vary the damping resistance thereof thereby to amplitude modulate said oscillations in response to movement of said element; a biasing network for said device included in said oscillating detector and comprising a resistor and a condenser having a time constant long for audio frequencies and short for sub-audio frequencies to provide a grid bias potential within said range which varies substantially only in response to sub-audio frequency amplitude modulation of said oscillations; and an anode load impedance for said device for deriving audio-frequency modulation components of said modulated oscillations.

4. A record player for reproducing sound from a record rotating at a sub-audible frequency comprising: an oscillation generator and plate-bend detector system in which the generator portion produces oscillations of superaudible frequency, said system including an electron discharge device having a grid voltage-anode current characteristic which is non-linear throughout a predetermined range of grid potentials; a transducer having a movable element, carrying a compliant stylus adapted to track the undulations of a movable record medium, coupled to said generator portion to amplitude modulate said oscillations in response to vibration of said stylus; a self-biasing network for said device included in said system and including a resistor and a condenser having a time constant long for audio frequencies and short with respect to said sub-audible rotational frequency to provide a grid bias potential within said range which varies substantially only in response to sub-audible frequency amplitude modulation of said oscillations; and an anode load impedance for said device for deriving audio-frequency modulation components of said modulated oscillations.

5. A record player comprising: an oscillating plate-bend detector having an oscillation generator portion for producing oscillations of superaudible frequency, said oscillating detector including a frequency determining circuit, comprising an inductance coil, for determining the frequency of said oscillations and further including a triode having a grid voltage-anode current characteristic which is non-linear throughout a predetermined range of grid potentials; a transducer having a movable conductive element, carrying a compliant stylus adapted to track the undulations of a rotatable record disc, coupled to said coil to vary the damping resistance re-

flected therein thereby to amplitude modulate said oscillations in response to vibration of said stylus; a self-biasing network for said triode included in said oscillating detector and comprising a resistor and a condenser having a time constant long for audio frequencies and short for sub-audio frequencies to provide an operating grid bias potential within said range which varies substantially only in response to sub-audio frequency amplitude modulation of said oscillations; and an anode load impedance for said triode for deriving audio-frequency modulation components of said modulated oscillations.

6. A record player for reproducing sound recorded on a rotatable record disc comprising: an oscillating plate-bend detector having an oscillation generator portion for producing oscillations of superaudible frequency, said oscillating detector including a triode having a cathode, a control grid, and an anode and having a grid voltage-anode current characteristic which is non-linear throughout a predetermined range of grid potentials; a frequency determining circuit included in said generator portion comprising the parallel combination of a condenser and a pair of serially connected inductance coils coupled between said anode and said control grid; a connection between the junction of said coils and said cathode; a transducer including one of said coils and having a movable conductive element carrying a compliant stylus and coupled to said one coil to vary the damping resistance reflected therein in response to vibration of said stylus for amplitude modulating said oscillations, said element having a compliance, measured at the tip of said stylus in the direction of movement thereof by the undulations of said record disc, greater than 10×10^{-7} centimeter per dyne; a self-biasing network for said triode included in said oscillating detector and comprising a resistor and a condenser having a time constant long for audio frequencies but short for sub-audio frequencies to provide an operating grid bias potential within said range which varies substantially only in response to sub-audio frequency amplitude modulation of said oscillations; and an anode load impedance for said device for deriving audio-frequency modulation components of said modulated oscillations.

7. A record player for reproducing sound re-

corded on a rotatable record disc comprising: an oscillating plate-bend detector having an oscillation generator portion for producing oscillations of superaudible frequency, said oscillating detector including a triode having a cathode, a control grid, and an anode and having a grid voltage-anode current characteristic which is non-linear throughout a predetermined range of grid potentials; a frequency determining circuit included in said generator portion comprising the parallel combination of a condenser and a pair of serially connected inductance coils coupled between said anode and said control grid; a connection between the junction of said coils and said cathode; a transducer including one of said coils and having a movable conductive element carrying a stylus and coupled to said one coil to vary the damping resistance reflected therein in response to vibration of said stylus for amplitude modulating said oscillations; a self-biasing network for said triode included in said generator oscillating detector and comprising a resistor and a condenser having a time constant long for audio frequencies but short for sub-audio frequencies to provide an operating grid bias potential within said range which varies substantially only in response to sub-audio frequency amplitude modulation of said oscillations; and an anode load impedance for said device for deriving audio-frequency modulation components of said modulated oscillations.

HENRY P. KALMUS.

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Certificate of Correction

Patent No. 2,489,379

November 29, 1949

HENRY P. KALMUS

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 14, line 22, strike out the word "generator";
and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.
Signed and sealed this 18th day of April, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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