ABSTRACT OF THE DISCLOSURE

A vibrato-producing apparatus which includes a conductive cylindrical body which is coated with dielectric material. The body is rotatable about its longitudinal axis at a rate which varies above and below an average rate during each revolution. A pair of record electrodes are positioned on opposite sides of the body. Signals, which are simultaneously applied to the two record electrodes, are stored simultaneously in opposite surface elements of the dielectric material. Thus, each element stores signals which have been frequency modulated above and below the input signal frequency. A read electrode is used to read the signals stored at each surface element.

BACKGROUND OF THE INVENTION

Field of the invention

This invention generally relates to signal-storing and reproducing devices and, more particularly, to a vibrato-producing apparatus.

Description of the prior art

In music, the term vibrato generally refers to cyclic vibrations in frequency of a signal in the audio frequency range, hereafter referred to as an audio signal or tone. The cyclic rate of variations is typically 4 to 8 cycles per second. The magnitude of the frequency variations above and below a mean frequency value, which is also referred to as the width of the frequency excursion, represents the vibrato range. A wide vibrato range is generally desirable since a wider vibrato range produces richer musical tones and greater orchestral effects.

In some musical instruments, vibrato is produced by generating the desired frequency variations at the source, as is the case with instruments such as the slide trombone or a string instrument. In the slide trombone the vibrato is produced by selectively positioning the slide while in a string instrument a similar effect is produced by the selective positioning of the player's finger on the string. In other instruments, such as electrical organs and pianos which contain little or no natural vibrato, vibrato may be produced by the addition of special devices.

Many such devices have been designed and are available commercially. Some devices employ signal phase shift and/or signal time delay techniques in order to produce the vibrato effect. In other devices electromechanical and mechanical principles are employed to produce the desired signal frequency variations. Although some of these devices operate with relative degrees of success, they have certain performance limitations which are quite undesirable. For example, devices based on signal phase shift techniques are capable of producing a very limited and narrow vibrato range, while others with sufficiently wide vibrato range are likely to produce flat and sharp tones which may be most disturbing to a listener.

The flat or sharp tones occur if at the instant of cessation of one note, the vibrato device produces a frequency at one end of its vibrato range, and the start of a succeeding note occurs when the produced frequency is at the other end of the vibrato range. Such disturbing tones are particularly present in devices with a wide vibrato range. Another disadvantage, characteristic of prior art devices, is the absence of means for sustaining a vibratoed signal in order to prevent sudden disruption of an audible note.

OBJECTS AND SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide a new improved vibrato-producing apparatus. Another object of the invention is to provide an apparatus capable of producing a wide vibrato range.

A further object of the present invention is to provide a relatively simple and inexpensive apparatus which is capable of producing a wide vibrato effect of a relatively wide range without attendant flat or sharp tones.

Still a further object of this invention is to produce a vibrato-producing apparatus with vibratoed-tone-sustaining characteristics.

These and other objects of the invention are achieved by providing a rotatable signal-storing device, such as a disc which has a portion of its surface, located about a center, coated with a signal-storing medium, a pair of record electrodes and a read electrode. The pair of record electrodes are positioned on opposite sides of the disc center about which the disc is rotated by a drive unit. Any incremental surface area of the signal-storing medium which passes by one record electrode passes, one half revolution later, by the other record electrode. The disc is rotated so that during each revolution, it is accelerated and decelerated. Alternately stated, the disc is rotated so that during each revolution, the velocity of the signal-storing medium, with respect to the record electrodes, varies above and below an average or mean velocity, with the maximum and minimum velocities occurring one half revolution period apart.

The audio signal to be vibratoed is applied to both record electrodes simultaneously, as the disc is being rotated. Consequently, after one complete revolution, at each incremental surface area of the medium, signals are stored whose relative wavelengths deviate from the wavelength of the input signal by equal lengths above and below it. That is, the frequencies of the signals stored at each incremental surface area of the medium are above and below the input signal frequency by equal values. Consequently, when these signals are sensed or read out by the read electrode and are supplied to a speaker, the resulting vibratoed tones which are both sharp and flat simultaneously tend to merge in the listener's ear. Thus, the undesired effect of flat or sharp tones is eliminated.

In order to provide a capability of sustaining the vibratoed signal, a conductive surface, coated with a dielectric material, is used. Signals are stored therein by electrostatic charging. The material is partially discharged each time it passes by the read electrode. Consequently, even after a note is no longer applied to the record electrodes, it is sustained in the signal-storing medium for several revolutions or read out cycles until it is completely discharged.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTIONS OF THE DRAWINGS

FIG. 1 is a diagram useful in explaining the invention; FIG. 2 is a velocity vs. time diagram; FIG. 3 is a side view of one embodiment of the invention; FIG. 4 is a diagram along lines 4—4 of FIG. 3; FIG. 5 is a diagram along lines 5—5 of FIG. 3; FIG. 6 is a front cross-sectional view of another embodiment of the invention; and

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FIG. 7 is a front cross-sectional view of yet another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Attention is now directed to FIG. 1 which is a diagram of the basic parts of the apparatus of the invention. Therein, numeral 11 represents a disc-like member which is rotatable about a center 12. The peripheral surface 14 of the disc is assumed to be coated with a material capable of storing signals applied thereto by record electrodes 16 and 17. The two record electrodes are positioned adjacent surface 14 on opposite sides of center 12, so that any incremental portion or area of surface 14 which passes adjacent one electrode, such as 16, appears and passes near the other record electrode one half revolution period later.

The two record electrodes 16 and 17 are connected to a signal source 20, so that the signal received therefrom is applied simultaneously by the two electrodes to opposite incremental surface areas, hereafter referred to as signal areas of the circular signals, of the circular signal-storing surface 14. The apparatus also includes a read electrode 18 which senses the signals stored in each signal-storing element passing thereby, and supplies signals related thereto to a utilization device 24. The latter may be an audio amplifier which drives a loudspeaker of an audio system. In FIG. 1, read electrode 18 is shown 90° apart from either of the record electrodes 16 and 17.

In addition, the apparatus of the invention includes a drive unit which is designated in FIG. 3 by numeral 25. Unit 25 will be described hereinafter in detail in conjunction with FIG. 3. Basically, the function of drive unit 25 is to rotate surface 14 about center 12 at a varying rate, so that during each revolution period, the surface 14 accelerates and decelerates. Alternately stated, the disc 11 is rotated so that during each revolution, the velocity of surface 14 with respect to the electrodes 16, 17 and 18, which are stationary, varies continuously, reaching maximum and minimum values with respect to a mean or average velocity one half revolution period apart.

Reference is now made to FIG. 2 wherein the velocity of surface 14 versus time, during three successive revolutions P1, P2 and P3 is diagrammed, and is designated by line 30. Points 31, 33, 35 and 37 represent a maximum velocity, points 32, 34 and 36, a minimum velocity and the points of intersection of line 30 with a line 40 represent a nominal velocity value.

The principles of operation of the apparatus of the invention will now be described in conjunction with FIGS. 1 and 2. Let it be assumed that source 20 provides record electrodes 16 and 17 with signals at a constant frequency \( f \), which are stored on surface 14 as it passes by each of the electrodes 16 and 17. Furthermore, let it be assumed that at a time \( t_1 \) (see FIG. 2) when the velocity of surface 14 is a maximum, designated \( V_m \), elements 41 and 42 of surface 14 are adjacent record electrodes 16 and 17 respectively, and that the member 11 is rotated clockwise as represented by arrow 45. Consequently, the input signals at frequency \( f \) are stored at elements 41 and 42 at a maximum surface velocity \( V_m \). Half a revolution later, at time \( t_2 \), the two elements 41 and 42 appear near electrodes 17 and 16 respectively. However, at time \( t_3 \), the surface velocity is a minimum, designated \( V_s \). Thus, it is seen that the input signals at frequency \( f \) are stored twice at each of elements 41 and 42, once at a surface velocity \( V_m \) and once at a surface velocity \( V_s \), where \( V_m \) and \( V_s \) deviate from a nominal velocity \( V \) by equal magnitudes or amounts. Consequently, the effective wavelength of the signals stored at velocity \( V_m \) is shortened with respect to the wavelength of the input signals. Alternately stated, signals at frequency \( f \) stored at minimum velocity \( V_s \) are frequency modulated to be of a frequency \( f_s \) above \( f \), and those signals stored at the maximum velocity \( V_m \) are frequency modulated to a frequency \( f_s \) below \( f \), where \( f_s = f - f_m \).

After one complete revolution, each signal-storing element of surface 14 stores signals with effective frequencies above and below the nominal frequency \( f \), with the frequency deviations being equal. The magnitude of frequency deviations of the signal stored at each element depend on the instantaneous velocity of the element with respect to the nominal velocity at the time of recording or signal-storing.

Each element may be thought of as storing two frequency modulated tones, one above and the other an equal amount below the frequency which is being vibrated. Since the two tones would always be read out simultaneously, the vibrato which they would produce would be both sharp and flat at the same time. Such a tone combination would not be disturbing to a listener, since his ear would tend to average the tones. Thus, the undesired effect due to the presence of sharp and flat tones, which is characteristic of prior art vibrato devices, is eliminated in the apparatus of the present invention.

The vibrato effect is actually produced by the varying frequency shift of the two vibrated tones stored as signals at each surface element. The varying frequency shift is produced by the varying velocities of surface elements as they pass by read electrode 18. For example, consider element 41 which at time \( t_1 \) is near electrode 16 stores a modulated signal \( f_s \) and at time \( t_2 \) when it is near electrode 17, it stores a modulated signal \( f_s \). Then a quarter of a revolution later, at time \( t_3 \), element 41 is at electrode 18. Since at time \( t_3 \), the velocity is \( V \), electrode 18 supplies device 24 with a combined tone whose effective frequency is \( f_s \). When element 41 is near electrode 18, element 43 is at electrode 17. From FIG. 2 and the foregoing description, it should be apparent that signals are stored in element 43 by electrodes 16 and 17 at time \( t_3 \) and \( t_2 \), respectively, when the velocity is \( V \). Thus, two unmodulated signals are stored in element 43. However, when at time \( t_3 \), element 43 is near electrode 18, the velocity is \( V_m \). Consequently, the frequency of each of the signals stored in the element is effectively increased to a maximum to produce a vibrated tone at the top of the vibrato range.

Element 44 opposite element 43 passes by electrodes 41 and 42 at times \( t_1 \) and \( t_2 \) when the velocity is \( V_m \) so that it also stores two unmodulated signals \( f_s \). However, when element 44 passes by electrode 18 at time \( t_2 \), the velocity is at a minimum value \( (V_s) \). Consequently, the two unmodulated signals are frequency shifted to produce a vibrated tone at the bottom of the vibrato range.

From FIGS. 1 and 2 it should be apparent that any other element on surface 14 stores two signals which when read out by electrode 18 result in the production of a vibrated tone which lies between the top and bottom of the vibrato range. In the particular example, the vibrato range equals the difference between the maximum and minimum frequencies produced when the surface velocity is at its maximum and minimum, respectively.

It should be pointed out that the position of read electrode 18 with respect to record electrodes 16 and 17 is not critical. It can be positioned at any convenient location as long as surface 14 passes thereby. However, the positioning of record electrodes 16 and 17 is critical. The two must be located on opposite sides of center 12 on a line extending therethrough so that any surface element, such as 41 which passes by one record electrode, such as 16, appears by the other record electrode one half revolution period later.

It should be pointed out that if desired, the invention may be practiced by incorporating a single record electrode rather than the two oppositely positioned electrodes, such as electrodes 16 and 17. It is appreciated that the use of the two record electrodes as taught herein result in the storing of two tones at each storage element.
of the storage surface, so that the effect of sharp and flat tones are not disturbing to a listener or their effect may be ignored, one record electrode would suffice, since the vibrato effect is actually produced by the frequency or Doppler shift of the tones, stored at the surface elements, which is then produced by the varying velocity of the storage surface 14 as it passes by the read electrode.

The characteristics of the record and read electrodes depend on the characteristics of the signal-storing surface 14. Peripheral surface 14 or a circular surface about center 12 on the front face of disc 11 may be coated with magnetic matter. In such a case the record electrodes would consist of a magnetic head and a magnetic read head, of the type used in conventional magnetic tape recorders. However, in order to provide a signal-sustaining characteristic, which as herebefore described is very advantageous, it is preferable to employ a signal-storing medium from which the stored signal is partially removed each time it is read out, so that after several revolutions, the stored signal is completely erased. This may be accomplished by employing a surface coated with a dielectric material in which signals are stored as electrical charges. Read out is accomplished by partial discharge of each surface element. In the following description the inverse will be described in conjunction with such a signal-storing medium.

Reference is now made to FIG. 3 which is a side view of one embodiment of the invention. FIGS. 4 and 5 are views along lines 4—4 and 5—5 of FIG. 3, respectively. Briefly, the apparatus includes a container 50 which is supported by a support structure 52. The rotatable disc 11 is supported in the container for rotation therein by a shaft 54 which extends into the chamber and is connected to the disc center 12. If desired, disc 11 may be replaced by any cylindrical body which can be rotated about each longitudinal axis. The container 50 has a hole sufficiently large to enable the shaft to pass therethrough without coming in contact with the container. A cover plate 55 is provided at one side of container 50 to afford access to its interior. The shaft 54 is supported for free rotation by bearing blocks 56 and 58 which are mounted on the support structure 52.

The drive unit 25 herebefore referred to as the unit which causes the rotation of member 11 is shown including a motor 60 mounted on structure 52. The motor's shaft 62 supported by bearing block 64 has a drive pulley 66 coupled to its end. A drive belt 68 couples pulley 66 to a mating pulley 70 which is supported by shaft 54. When the motor is energized, the shaft 62 rotates, in turn rotating pulley 66 which by means of belt 68 rotates pulley 70. Thus, shaft 54 and the particularly disc member are rotated. To produce the varying rate of rotation in order to produce the varying velocity of the disc surface, biasing means are coupled to pulley 70 in order to vary the torque, applied thereto. In FIG. 3 the biasing means comprise a spiral spring 72, connected at one end to an idler 74, which is mounted on a short stub 75 which extends from the back face of pulley 70. The other end of the spring is connected to a control member, such as a handle 76 which is pivotally supported by structure 52 at a pivot point 77. Thus, spiral spring 72 is supported so that its longitudinal axis is substantially perpendicular to the axis about which shaft 54 rotates. By varying the maximum spring tension, which is achieved by adjusting the position of control member 76. Referring now to FIG. 4, the peripheral surface 14 of disc 11 is shown comprising a dielectric surface or layer 80 which has a conductive backing 82. A preferred arrangement comprises making the disc 11 or at least the conductive backing portion thereof, of aluminum, with the outer peripheral or dielectric layer 80, made of aluminum oxide formed by anodizing the aluminum.

Extending through the container 50 to afford electrical communication with the dielectric layer 80 are the record electrodes 16 and 17 and the read electrode 18. It has been found that conductive rubber, which consists of rubber impregnated with graphite affords the required connection with the dielectric layer 80 and yet is soft so as not to gouge the layer as it is rotated by these electrodes.

It is appreciated that a minimum pressure must be applied between the dielectric layer 80 and the electrodes to provide proper electrical contact. In order to compensate for the adverse effect of friction in a preferred embodiment, a lubricating fluid 85 is poured into the bottom of container 50 through the opening provided when the cover plate 55 is removed. Sufficient fluid is poured into the container so that the disc 11 dips into the fluid as it rotates. Thereby, a lubricating fluid is removed from excess lubricating fluid and for leaving a thin film on the surface of the cylinder. The wiper 86 may be of any soft material which still has sufficient rigidity to remove the excess fluid. The wiper is supported from the container.

The lubricant 85 may be an electrically conductive fluid which will cover the dielectric in the form of a thin film. The conductivity of the fluid allows electrical energy to pass between the electrode and the dielectric and thereby forms a more intimate electrical contact, minimizing the effects of porosity and irregularities in the dielectric. Also, it enhances the surface tension in the region of friction. The conductivity of the lubricating fluid, however, should not be such as to cause a discharge between the reading and writing electrodes.

A preferred resistance for the fluid is one which ranges between 10 megohms per cubic centimeter to 200 megohms per cubic centimeter. A preferred fluid which provides both the lubricating and the conductive qualities desired is a polyalkylene oxide derivative which is sold by the Union Carbide Company under the trade name of "Ucon" LB 63 fluid. This fluid is mixed with alcohol until its conductivity reaches a desired value. However, any lubricating fluid having the desired conductivity may be used instead.

It should again be stressed that although in FIGS. 1 and 4 the signal-storing medium is shown at the peripheral surface of the rotatable disc 11, the medium such as the dielectric layer 80 may be located as a circular layer on the face of the disc 11. Such an arrangement is shown in FIG. 6 in which elements like those previously described are designated by like numerals. If desired, the face of disc 11 may define a plurality of concentric tracks or rings of signal-storage material, with each track being associated with a pair of record electrodes and a read electrode. One example of such an arrangement is shown in FIG. 7 wherein numerals 91, 92 and 93 designate three tracks. Record electrodes 91a and 91b, 92a and 92b, and 93a and 93b are positioned to store signals in tracks 91, 92 and 93, respectively. As indicated by arrow 78 (FIG. 5), the range of velocity change is controlled, thereby controlling the vibrato range.

The use of the spring in combination with the pulley 70 to vary the velocity of the disc surface has been found to be highly advantageous from several points of view. The combination is very simple, inexpensive and highly reliable. Also, it is very easy to vary the range of velocity change since all that is required to accomplish the variation is a change of maximum spring tension which is achieved by adjusting the position of control member 76.
the vibrato ranges of the tracks are different. The outputs of the three read electrodes 91c, 92c and 93c are shown supplying to a switch 92, which can be opened to supply the output of any one or of a combination of the three read electrodes to the utilization device 24. Thus, with the novel arrangement shown in FIG. 7, any combination of up to three vibratoed tones which are vibratoed at different ranges may be produced and utilized. It is apparent that any desired number of tracks may be employed. It should further be pointed out that either electrostatic or magnetic-signal storing techniques may be employed. For example, the multitrack disc 11, shown in FIG. 7, may be a multitrack magnetic disc in which case, the various electrodes would be write and read magnetic types.

There has accordingly been shown and described herein in a novel vibrato-producing apparatus. It consists of a signal-storing surface, a pair of record electrodes and a read electrode positioned adjacent the surface. The surface is cyclically rotated at a varying velocity so that each element thereof passes by one record electrode and one half revolution later it passes by the other record electrode, both of which apply the same input signal for storage in the surface. Thus, after one revolution, each surface element stores signals at frequencies above and below an average frequency of the input signal. The read electrode responds to the two signals which are stored in each element and which are frequency shifted by an equal frequency value or amount, which is a function of the velocity of the element as it passes by the read electrode. However, since the velocities of adjacent surface elements are different, the signals at the various elements are phase shifted by different or varying amounts. It is this varying frequency shift which produces the vibrato effect. The vibrato range is a function of the difference between the maximum and minimum velocities.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.

What is claimed is:

1. A vibrato-producing apparatus comprising:
   a signal-storing medium rotatable about a center;
   first and second electrode means disposed adjacent said medium, for applying signals, simultaneously supplied to said first and second electrode means to said signal-storing medium, said first and second electrode means being positioned on opposite sides of said center on a straight line extending therefrom;
   means for feeding said medium about said center at a varying rate during each of a succession of equal duration cycles, said rate varying during each cycle above and below a preselected average rate of rotation; and
   a third electrode means positioned adjacent said rotating signal-storing medium for removing signals from said medium element passing thereby.

2. The vibrato-producing apparatus as recited in claim 1 wherein said signal-storing medium includes a conductive surface and a dielectric material covering at least a portion of said conductive surface which defines a circle about said center.

3. The vibrato-producing apparatus as recited in claim 2 further including lubricating means having a predetermined conductivity and means for applying said lubricating means to said dielectric material in a thin film to be present at said first, second and third electrode means.

4. The vibrato-producing apparatus as recited in claim 3 wherein said lubricating means is a lubricating fluid and said means for applying said lubricating means include a reservoir for said fluid through which said dielectric material moves when said conductive surface is rotated, and means for limiting the amount of fluid carried by said dielectric material after said dielectric material has passed through said reservoir.

5. A vibrato-producing apparatus comprising:
   a signal-storage medium of predetermined configuration and signal storage characteristics;
   signal record means to which a signal in the audio frequency range is supplied, said signal record means being disposed adjacent said signal-storage medium for storing therein the signal received thereby;
   drive means for varying the relative velocity of said medium with respect to said signal record means at a variable rate during each of a succession of equal duration cycles, whereby during each cycle said medium moves with respect to said signal record at a velocity which varies above and below an average velocity; and
   signal read means positioned adjacent said signal-storage medium which is moved at said varying velocity for reading out said signals stored in each element of said signal-storage medium.

6. The vibrato-producing apparatus as recited in claim 5 wherein said signal record means comprises at least one record electrode, and said signal read means comprises a single read electrode.

7. The vibrato-producing apparatus as recited in claim 6 wherein said signal-storage medium comprises a plurality of concentric signal-storage tracks on a disc rotatable about its center at a varying rate by said drive means, said signal record means including at least one record electrode disposed adjacent each track for storing signals therein, and said signal read means includes a single read electrode adjacent each track for reading the signal stored in each track element as said track is moved by said read electrode.

8. A vibrato-producing apparatus comprising:
   a movable conductive surface;
   a dielectric material covering said surface;
   first and second electrode means for applying simultaneously the same signals to said dielectric material;
   means for moving said surface coated with the dielectric material at a varying velocity during each of a succession of equal duration cycles with each element of said surface moving at a velocity which is being adjusted to each of said first and second electrode means at half cycle intervals, the velocity of said surface varying during each cycle above and below an average velocity with the maximum and minimum velocities occurring at half a cycle interval apart; and
   third electrode means positioned adjacent said coated surface for reading signals from each element of said dielectric material which moves adjacent thereto.

9. The vibrato-producing apparatus as recited in claim 8 including a lubricating fluid having a predetermined conductivity, and means for continuously applying said fluid to said dielectric material in a thin film to be present at said first, second and third electrode means.

10. The vibrato-producing apparatus as recited in claim 9 wherein said means for continuously applying said fluid to said dielectric material in a thin film includes a reservoir for said fluid through which said dielectric material on said moveable conductive surface is moved, and brush means for removing any fluid excess after said dielectric material has passed through said reservoir.

11. A vibrato-producing apparatus comprising:
   a conductive cylindrical body, defining a longitudinal axis;
   a dielectric material covering a selected portion of the surface of said body;
   a container;
   means for rotatably supporting said cylindrical body within said container;
means for rotating said body about its longitudinal axis at a varying annular rate of rotation during each complete revolution, said rate of rotation varying above and below a mean rate of rotation;
first and second electrode means positioned adjacent said cylindrical body on opposite sides of said longitudinal axis, said first and second electrode means affording electrical connection with said dielectric material for storing therein signals which are simultaneously applied to said first and second electrode means;
third electrode means affording electrical connection with said dielectric material to receive signals stored in said material; and
lubricating fluid having a predetermined conductivity, said lubricating fluid being within said container in an amount sufficient to insure that the dielectric material on the surface of said body comes in contact therewith.

12. The vibrato-producing apparatus as recited in claim 11 wherein each of said first, second and third electrodes is a conductive rubber member and said fluid is a mixture of a polyalkylene oxide derivate and alcohol.

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