May 22, 1956 R. E. WILLIAMS 2,746,334

TONE WHEEL VIBRATO MEANS

Filed June 3, 1950 2 Sheets-Sheet 1

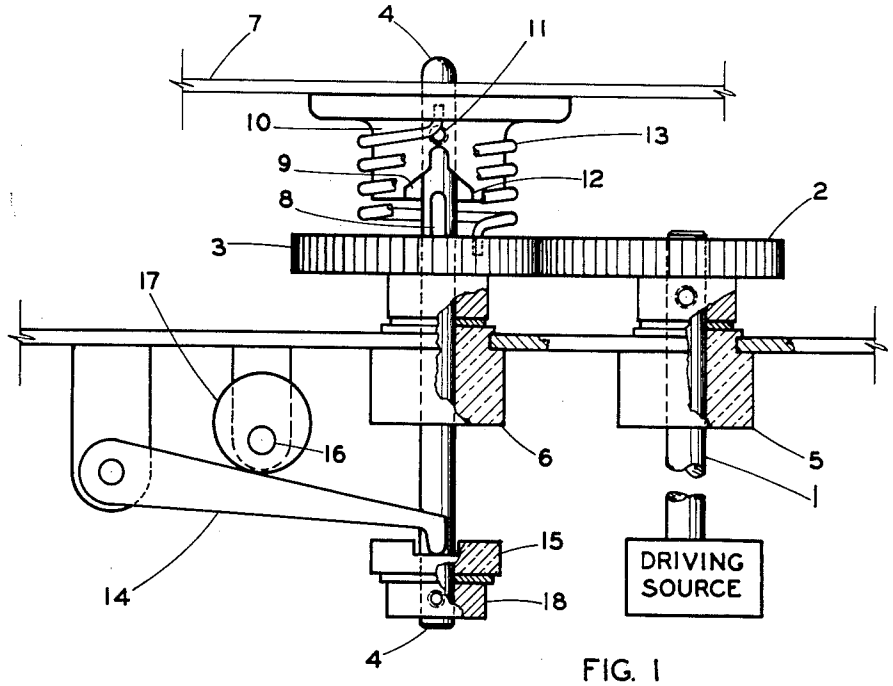


FIG. 1

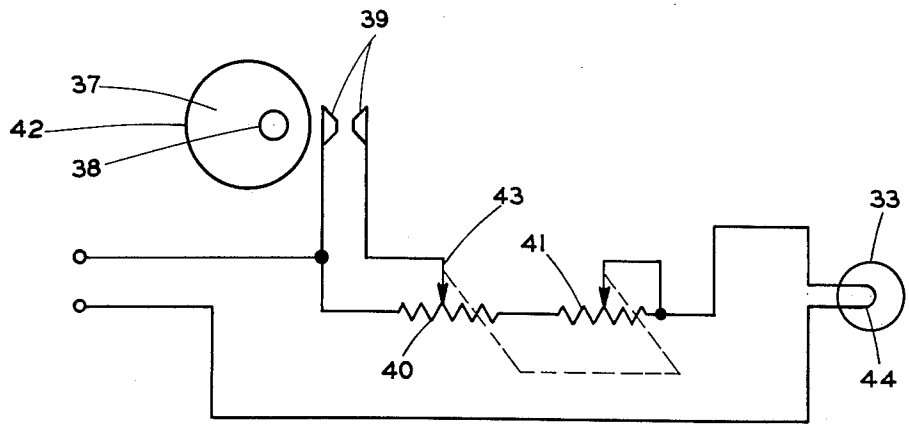


FIG. 2

INVENTOR

Richard E. Williams

May 22, 1956 R. E. WILLIAMS 2,746,334

TONE WHEEL VIBRATO MEANS

Filed June 3, 1950 2 Sheets-Sheet 2

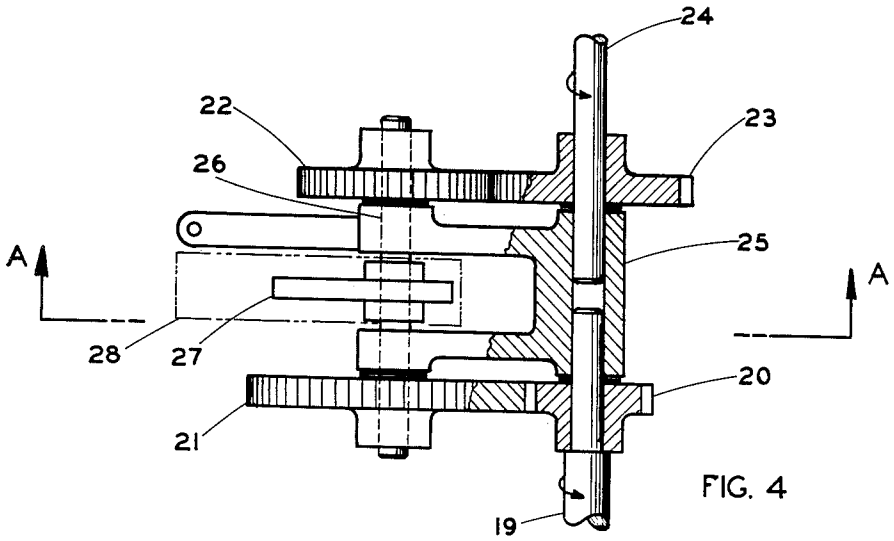


FIG. 4

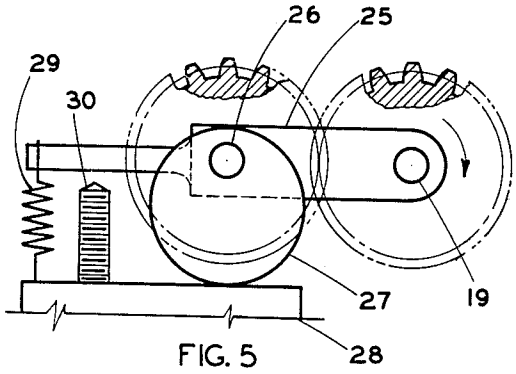


FIG. 5

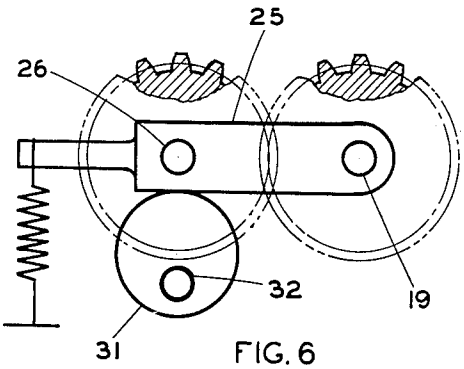


FIG. 6

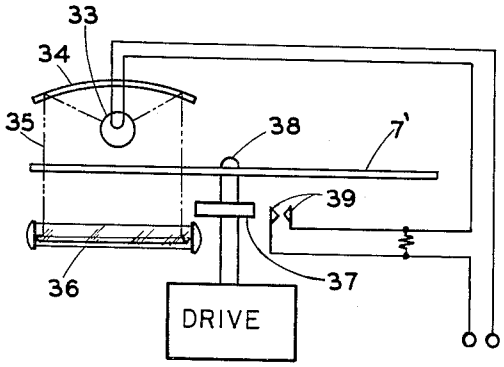


FIG. 3

INVENTOR

Richard E. Williams

United States Patent Office 2,746,334 Patented May 22, 1956

2,746,334

TONE WHEEL VIBRATO MEANS

Richard E. Williams, Manchester, N. H., assignor to Wilbespan Research Labs, Inc., Manchester, N. H.

Application June 3, 1950, Serial No. 165,889

2 Claims. (Cl. 84—1.25)

This invention relates to improvements in musical instruments in which pitches are generated by means of moving tone wheels, and more particularly, to means of applying enhancing audible effects commonly known as vibratos and tremulants to the tone generated by these tone wheels.

Any tone consists of two basic qualities; that of loudness and that of pitch. It has been found that for the most pleasing audible effects upon listening to a steady state tone it is desirable to relieve the monotony of sustenance inherent in such a tone by introducing periodic loudness or pitch variations at a rate recurrent between four and twelve times a second. These rates are generally referred to as the vibrato or natural tremulant range. Although the terms "vibrato" and "tremulant" are used interchangeably to a great extent, more recently it has become the practice to refer to the recurrent pitch variation as vibrato and the recurrent loudness variation as tremulant. For purposes of clarity the latter terminology will be used throughout the following description.

I therefore intend, as an object, the production of frequency vibrato in tone wheel pitches simply and expeditiously.

Another object is to provide an inexpensive practical way of controlling the amount of frequency vibrato to be imposed upon tones generated by a tone wheel.

Again, the invention will be found to reside in a method of introducing periodic variations in speed of a tone wheel maintaining direct coupling to a driving source and constant average speed.

Further, the invention has for its object means for introducing loudness or amplitude tremulant control in a musical instrument of the photoelectric type using a tone wheel.

Still another aim is that of introducing a frequency vibrato with a controllable recurrence rate to a tone wheel.

The foregoing and other objects will manifest themselves as the following description progresses, references being had to the accompanying drawings, in which:

Fig. 1 is a driving train for a tone wheel providing control of recurrent speed deviations and, therefore, amount of frequency vibrato;

Fig. 2 is an electrical circuit supplying energy to a light source for a photo-electric musical instrument in which a cam causes pulsations in light intensity;

Fig. 3 is a simplified diagram of a photo-electric type instrument utilizing the principle shown in Fig. 2;

Fig. 4 is a differential gearing train showing a method of introducing recurrent speed variations in the output shaft;

Fig. 5 is a view along line A—A of Fig. 4; and

Fig. 6 is a substitution for the device shown in Fig. 5 in which the axial displacement of the differential gear is provided by independent means.

As is well known to those skilled in the art, the pitch of a tone generated by a track on a tone wheel is dependent upon the cycling speed of the tone wheel in such manner that any increase in that speed will cause a

corresponding rise in pitch. For instance, if a tone wheel which rotates ten times a second is increased in angular velocity by 10% resulting in a new speed of eleven revolutions a second, any pitch generated by a soundtrack upon that tone wheel will be increased by a corresponding amount, 10%. Therefore, a 800 C. P. S. note will rise in pitch to 880 C. P. S. It is thus seen that intentional pitch variations can easily be provided by periodically varying the angular velocity above and below its mean value. It has been found that the percentage of deviation most pleasing to the human ear lies between one and three percent, although for certain tonal effects it is desirable to introduce no vibrato of this type at all. One important consideration is necessary. The percentage of deviation must be exactly similar both above and below the mean angular velocity of the tone wheel if the average pitch is to remain the same under conditions of vibrato "on" and vibrato "off." It is interesting to note that a keen musical ear is capable of detecting variation in average pitch to an accuracy in the order of .05%.

Referring to Fig. 1, a tone wheel drive embodying a simple method of obtaining a desired variation in cyclical velocity with controllable means for the percentage of deviation is shown. A countershaft **1** rotating at an angular velocity falling within the vibrato range (4–12 R. P. S.) is connected to a constant speed driving source providing this velocity. This driving source may be a synchronous electric motor or any other conventional relatively constant speed motor device and is indicated schematically in Fig. 1 by the block labeled "Driving source." Affixed to the countershaft **1** is an eccentric gear **2** meshing another eccentric gear **3** rotating loosely upon the tone wheel spindle **4**. Although the two meshing gears **2** and **3** are eccentric, it is possible to maintain their axes at a given distance dictated by the location of their respective journaling bearings **5** and **6**, provided the "high" on one gear meshes the "low" on the other. Because the effective gear ratio changes periodically as they rotate, the driven gear **3** will rotate at a periodically varying angular velocity, the speed variation component itself recurrent at the cyclical velocity of either of the two gears **2** and **3**. Because the driven gear **3** is loosely journaled upon the spindle **4** no motion would normally be imparted to the tone wheel spindle **4** or the tone wheel itself **7**. To provide absolute speed transmission a pin **8** affixed to the driver gear **3** projects within an aperture **9** cut into the hub of a flange **10**. The hub **10** is affixed to the tone wheel spindle **4** by means of a set screw **11**. It will be seen that as the driven gear **3** commences to rotate its pin **8** will strike an appendage **12** on the hub **10** and cause the spindle shaft **4** to rotate. Assuming the tone wheel **7** to have appreciable mass, an eventual steady state will be reached where the initial inertia of the tone wheel is overcome and its sustained moment of inertia will provide a fly-wheel effect tending to keep its angular velocity constant. Because the driven gear **3** has a speed variation component oscillatory in nature which was introduced by the eccentric coupling gears **2** and **3**, it will periodically swing back and forth upon the tone wheel spindle **4**. The aperture **9** is designed in such manner that the maximum swing of this type that is encountered by the pin **8** will lie within the physical limits of the aperture **9**. Under normal operating conditions, therefore, the pin **8** will contact the hub **10** only long enough to bring the tone wheel **7** to its steady state average velocity where the power component of the load presented to the tone wheel spindle **4** is independent of the tone wheel inertia. A spring **13** is provided to maintain the pin **8** in a central position within the aperture **9** under this steady state condition. The oscillatory motion of the pin **8** will, therefore, not be imparted to the tone wheel spindle **4** as the mass of the tone wheel **7** tends to keep

the spindle 4 rotating at a constant velocity by means of its fly-wheel action. This is the vibrato "off" condition. It will be noticed that an increase in the effective mass of the tone wheel 7 aids this "off" condition by acting as a filter which removes the speed variation component provided by the meshing eccentric gears 2 and 3.

When it is desired to transmit all or a portion of the speed variation component to the tone wheel 7 and obtain a resultant frequency vibrato, engagement of the pin 8 and the hub 10 is controllably insured by means of a lever arm 14 upon which is journaled a bearing 15. A shaft 16 operable by manual control has affixed to it an eccentric cam 17 brought into engagement against a lever 14 through rotation. As the high point on the cam 17 presses against the lever arm 14 the bearing 15 presses against a collar 18 affixed to the tone wheel spindle 4. This motion in effect pulls the entire tone wheel spindle 4 through the eccentric gear 3 in such manner that the aperture 9 is pulled down over the pin 8. It will be seen that as the spindle is pulled in this manner the range through which the pin 8 can oscillate will become more and more restricted within the aperture 9. The restriction will cause periodic collision between the pin 8 and the hub 10 in such manner that the tone wheel 7 has periodically applied to it an accelerating force in the direction of rotation followed by a retarding force opposing the rotation as the pin 8 strikes the right and left hand sides respectively of the aperture 9. If more and more force is applied to the lever 14 by means of the cam 17 a point is reached where eventually the pin 8 projects into the apex of the aperture 9 and, therefore, transmits its entire oscillatory motion to the tone wheel 7. It will be noticed that at the moments that retarding or accelerating forces are applied to the tone wheel 7 no resilient coupling is present between the driving source and the tone wheel 7 so that the tone wheel mass will not appreciably reduce the amount of vibrato percentage deviation. It is also interesting to notice that the entire power providing both the steady state velocity and vibrato variations to the tone wheel 7 is derived from the single driving source. The spring 13 provides compressive pressure between the flange 10 and the driven gear 3 in such manner that the spindle 4 will return to the vibrato "off" position upon returning the controlling cam 17 to a low leverage position.

Another method of introducing a speed variation and, therefore, frequency vibrato to a tone wheel is that shown in Fig. 4. In this figure a driving shaft 19 having affixed to it a driving gear 20 meshes with intermediate gears 21 and 22 in turn transmitting the power to a driven gear 23 affixed to the tone wheel spindle 24. The intermediate gears 21 and 22 are differentially related to the driving gear 20 and the driven gear 23 in such manner that any axial displacement of the differential gears 21 and 22 will introduce a variation in the velocity of the output shaft 24. The driving shaft 19 and the output shaft 24 are journaled within a single housing 25 in such manner that they operate coaxially without physical connection other than that imparted by the differential gears 21 and 22. The differential gears 21 and 22 are affixed to a shaft 26 journaled within the housing 25 in such manner that the shaft 26 can rotate about the shafts 19 and 24 as an axis. It can be seen, therefore, that the entire housing 25 can be rotated, in which case axial displacement of the differential gears 21 and 22 is accomplished without allowing any of the gears in the gear train to fall out of mesh. Under normal conditions corresponding to vibrato "off" the housing 25 is held at a fixed position. Under this method of operation the driving shaft 19 transmits energy through its gear 20 to an intermediate gear 21 affixed to a shaft 26. The shaft 26 in turn imparts the energy to the output shaft 24 by means of the meshing gears 22 and 23. This is a simple gear train under this fixed housing operation.

Normally the shaft 26 will be caused to rotate at a natural vibrato rate or sub-multiple thereof by choosing the proper ratio between the driving gear 20 and the first differential gear 21. If the shaft has affixed to it an irregularly shaped cam 27 which contacts a fixed rest 28 rotation of the shaft 26 will result in a periodic oscillation of itself about the axis created by shafts 19 and 24. When the motion of the differential shaft 26 is in the direction of the driving shaft 19 it will tend to make the output shaft 24 run closer in angular velocity to that of the driving shaft 19. The opposite occurs if the motion of the differential shaft 26 opposes the original direction of motion of the driving shaft 19. Usually the driving shaft 19 will rotate at a speed higher than that of the output shaft 24 so that oscillatory displacement of the shaft 26 will bring about changes in speed increasing as the shaft 26 moves in the direction of the drive shaft 19 and vice versa. Referring to Fig. 5, a view along A—A of Fig. 4, it will be seen that the cam 27 will tend to periodically cause the shaft 26 to move in direction of rotation of the drive shaft 19 and the spring 29 will provide the opposite motion. If the drive shaft 19 were to operate in a counter-clockwise direction, opposite to that shown, it is possible to dispense with the spring 29 if sufficient frictional coupling is encountered between the housing 25 and the drive shaft 19 to return the shaft 26 to its recoil position automatically.

Under the situation shown in Figs. 4 and 5, the differential shaft 26 is assumed to be rotating at a natural vibrato rate so, therefore, will impart speed variations at this same rate. Adjustment of a limiting screw 30 in Fig. 5 provides a means for limiting the effect of the cam 27 and, therefore, controlling the amount of vibrato introduced. If the differential shaft 26 is assumed to be rotating at one-half the desired vibrato rate it is merely necessary to use a cam having two high spots instead of the one shown in 27; one-third the vibrato rate, three high spots, etc.

Still another method of introducing vibrato by differential means in which the actual recurrent rate is controllable (amount of deviation has been shown controllable) is shown in Fig. 6. In this figure the eccentric cam 31 is rotated by independent means consisting of a shaft 32 connected to an appropriate driving source providing speed variation manually controllable. By this method rocking motion of the housing 25 can be varied in rate of recurrence as well as percentage of deviation as described in reference to Figs. 4 and 5.

An interesting point to note is that the instantaneous pitch provided by the tone wheel does not depend upon the instantaneous position of the differential gears but upon the speed with which the gears are changing position, or velocity of displacement. Because the time interval between recurrent vibrato cycles has been assumed constant, the amount of eccentricity of the cam will automatically control the percentage of deviation in pitch.

A method of introducing tremulant, or loudness variation, in a musical instrument having a tone wheel in the form of a light screen passing between a light source and a photo-electric cell is shown in Figs. 2 and 3. More particularly referring to Fig. 3, a musical instrument of this type consists of a light source 33 with suitable optics 34 producing a beam of light 35 which passes through transparent sections of a tone wheel 7' rotating in front of a photo-electric cell 36. Variations in the light allowed to impinge upon the photocell 36 produces corresponding variations in the voltage output from the photocell 36 which can be amplified and transduced to sound by conventional means.

If the tone wheel 7' is assumed rotating at a natural tremulant rate or sub-multiple thereof, a cam 37 can be affixed to the spindle 38 upon which the tone wheel 7' is mounted. Referring to Fig. 2, the cam 37 periodically closes a pair of contacts 39 shunted by a variable resistance 40 and in series with the light source 33. An additional variable resistance 41 is provided in series with

the light and mechanically coupled to aforesaid resistance **40** in such manner that operation to be described does not vary the average intensity of the light source **33**. It is to be understood that the loudness of the tone produced by the tone wheel **7'** is dependent upon the intensity of the light source **33**.

In Fig. 2 a cam **37** having one high point **42** which operates at a natural tremulant rate is shown. As the spindle **38** rotates with the tone wheel **7'** in Fig. 3 it closes and opens the contacts **39** once per revolution, or at the aforesaid natural tremulant rate. Depending upon the setting of the variable resistance **40** in Fig. 2 the contacts **39** while closed will allow more current through the light source **33** thus increasing its intensity. It will be noticed that when the arm **43** of variable resistance **40** is in the extreme left-hand position the contacts **39** are effectively short circuited, and will, therefore, have no effect upon the circuit as a whole. As the arm **43** is moved to the right, the contacts **39** are shunted across more and more of the resistance **40** and, therefore, will have greater effect upon the circuit. Generally speaking, as the effect of the contacts **39** is increased in the manner just described, the average light intensity of the light source **33** will increase. To correct this condition which in operation would result in an increase of overall loudness of the tones produced, the variable resistance **41** is coupled in such manner that its resistance increases as the shunting effect of the contacts **39** becomes more pronounced. Although the contacts **39** would tend to very abruptly increase and decrease the intensity of the light source **33** the circuit parameters may be devised in such manner that the inherent time lag in the incandescent light source filament **44** will eliminate any clicks that may result.

If the tone wheel **7'** in Fig. 3 is assumed rotating at a sub-multiple of a tremulant rate it is merely necessary that the cam **37** have a number of high points corresponding to the sub-multiple utilized. It is also possible to operate the cam **37** independently of the tone wheel spindle provided that the recurrence of contact closure is at a natural tremulant rate.

Although for purposes of simplicity a tone wheel in the form of a disc is shown throughout, it is to be understood that equivalent tone producing bodies in the forms of cylinders, etc. will produce substantially the same results as those described. The tone wheel itself may have upon it a sound-track in many forms such as that of material varying in magnetic strength, conductivity, transparency, etc. without effecting the primary and basic principles described herein. I, therefore, wish to include within the scope of my claims all such similar constructions which effectively produce the results described in the basic manner herein disclosed.

What is claimed is:

1. In a musical instrument having a moving tone wheel, means for controllably introducing a frequency vibrato in the pitch produced by said tone wheel, comprising drive means operatively connected to said tone wheel for imparting a basic constant speed to said tone wheel, said drive means including drive element means adapted for impressing an oscillatory speed variation upon said basic constant speed upon oscillatory movement of said drive element means, and operable control means moving at a vibrato rate and mounted for imparting such oscillatory displacement to said drive element means.

2. In a tone generator, tone wheel means having inertia and comprising a tone record element, motor means having a speed comprising a constant component and a smaller oscillatory component, a resilient coupling connecting said motor means to said tone wheel means and adapted to resiliently substantially absorb said oscillatory component in cooperation with said inertia for transmission of substantially only said constant component to said record element, and adjustable play mechanical clutch means connected drivingly in parallel with said coupling for positively transmitting an adjustable degree of said oscillatory component to said record element.

References Cited in the file of this patent

UNITED STATES PATENTS

2,143,236	Birk	Jan. 10, 1939
2,221,188	Hammond et al.	Nov. 12, 1940
2,314,496	Hammond	Mar. 23, 1943
2,460,868	Appel	Feb. 8, 1949
2,552,572	Mikina	May 15, 1951
2,603,084	Waddell	July 15, 1952