United States Patent Office

3,413,403
3,413,403 VIBRATO AND TREMOLO SYSTEM
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11 Claims. (Cl. 84—1.25)

ABSTRACT OF THE DISCLOSURE

A vibrato system for an electrical musical instrument or the like wherein an audio signal from the instrument is summed with two phase-shifted versions of the audio signal in a summing network to provide a vibrato output. One phase-shifted version of the audio signal is developed by a variable phase-shifting circuit whose input is the audio signal and the other phase-shifted version of the audio signal is developed by a second variable phase shift circuit whose input is the output of the first phase shifting circuit. A vibrato control signal varies the phase shift introduced in the first and second phase-shifting circuits substantially in unison.

This invention relates to circuits for producing vibrato and/or tremolo in electrical musical instruments.

As the terms vibrato and tremolo are used in the description and claims which follow, vibrato means a variation of pitch and is produced by frequency or phase modulation of signals, whereas tremolo means a variation of loudness and is produced by amplitude modulation of signals. The signals to be modulated, however, cover a wide range of frequencies, so the modulation differs from ordinary frequency or amplitude modulation where a single carrier frequency is varied in frequency or amplitude, often in proportion to the variations of an audio frequency signal.

An object of this invention is to provide an improved system for producing substantially pure vibrato in the sound from an electrical musical instrument.

Another object of the invention is to provide a circuit which can produce either vibrato or tremolo or both effects simultaneously.

Another object of the invention is to introduce vibrato by producing a dynamic phase shift in a signal over a wide range of frequencies without introducing substantial amplitude variations.

A further object of the invention is to provide an improved vibrato system having all-pass transmission characteristics; i.e., one which passes a very wide range of signal frequencies.

Another object of the invention is to isolate control signals from the audio signals in a vibrato system.

A further object of the invention is to effect modulation in a vibrato system by variations of light.

Other objects and features of the invention will be apparent from the description which follows considered with the accompanying drawings, in which:

FIG. 1 is a simplified block diagram illustrating a vibrato and tremolo system embodied in an electric guitar.

FIG. 2 is a block diagram of a vibrato and tremolo system in accordance with the invention.

FIG. 3 is a schematic diagram for a vibrato and tremolo system which constitutes one embodiment of the invention.

FIG. 4 is a schematic diagram for another embodiment of the invention.

FIG. 5 is a plan view of a light dependent resistor included in the system of FIG. 4.

FIG. 6 shows a light bulb and a light dependent resistor encapsulated with plastic.

FIG. 7 illustrates certain waveforms produced in the operation of the system of FIG. 4.

FIG. 8 is a curve showing the relationship between phase angle and frequency of signals transmitted by the circuits of FIGS. 3 and 4.

FIG. 9 is a curve similar to FIG. 8 but with frequency plotted on a logarithmic scale.

In FIG. 1, the sound system for an electric guitar 10 has been illustrated in block diagram form. It is to be understood that the utility of the vibrato and tremolo system of the invention is not limited to electric guitars, but this is a major application for the invention. Electric organs are another instrument in which the system is useful. Electrical signals are derived from vibrations of the strings of guitar 10 by a pick-up device (not shown) which ordinarily includes a coil and magnet mounted under the strings such that as a string vibrates, it varies the flux linking the coil, thereby inducing voltage in the coil. Signals from the pick-up device are amplified by a pre-amplifier circuit 12 and are fed to the vibrato and tremolo system 14 where either amplitude modulation (tremolo) or frequency modulation (vibrato) may be introduced into the signals. It is sometimes desirable to introduce both vibrato and tremolo, but system 14 can produce either effect in a reasonably pure form. Reverberation may be added to the signals in unit 15, and the output from unit 15 is amplified by a power amplifier 16 and supplied to one or more loudspeakers 18 which transduce the output to sound.

FIG. 2 is a block diagram of a vibrato and tremolo system 14 in accordance with the invention. These are two phase shifting stages 20 and 22 coupled in cascade relation between a signal input terminal 24 and a signal output terminal 26. The filters 28 and 30 of stages 20 and 22 respectively are varied by control signals supplied from a control device 27 so as to modulate input signals fed to terminal 24. The outputs of variable filters 28 and 30 are inverted in phase by inverting amplifiers 31 and 32, and output signals are supplied from the inverting amplifiers via lines 33 and 34 to a summing network 35 where they are summed with the input signal before being supplied to network 35 over line 36. The output signals which appear at terminal 26 are audio frequency signals modulated in frequency at a vibrato rate determined by control device 27. Normal rates for either vibrato or tremolo are from four to ten cycles per second, but system 14 is not restricted to these rates. In both natural and artificial music, a vibrato rate as high as ten percent of the audio frequency can occur.

It has been found that by weighting the amplitudes of the three signals which are summed in network 35 in the ratio of one part of input signal to four parts of each of the phase-shifted signals, and by making the time constants of variable filters 28 and 30 equal, it is possible to produce pure vibrato in the output signal which appears at terminal 26. In this case, the overall transmission characteristic of system 14 is that of an all-pass network; that is, the system passes a very wide range of frequencies without attenuating any particular frequencies more than others. If the gain of system 14 is unity, it will pass all frequencies in a wide range without attenuating any frequency. The individual filters 28 and 30 may be either high-pass or low-pass filters, but the overall system 14 nevertheless has all-pass transmission characteristics due to the 1:4:4 ratio in which the input signal and the two phase-shifted signals are summed in network 35.

Vibrato is introduced by varying the time constants of filters 28 and 30 at the desired vibrato rate. This can be accomplished by varying a resistance, a capacitance or an inductance in filters 28 and 30, and in the case of
a resistance variation, it can be accomplished advantageously by the use of a light dependent resistor illuminated by a light, which is varied by the vibrato rate by the control device 27. If desired, both tremolo and vibrato can be added to the signals, and it is possible to adjust system 14 so that it produces tremolo with little or no vibrato.

The circuitry of one embodiment of the invention is illustrated in FIG. 3. The sections of the circuit corresponding to the blocks in FIG. 2 have been enclosed in dashed lines in FIG. 3. The input signal is supplied to terminals 44 and 46 and the output signal appears across terminals 48 and 50. Coupling capacitors 45 and 47 are connected respectively to terminals 44 and 48. In this embodiment, circuit 40 is isolated from the control device 27. Operating potential for circuit 40 is applied to buses 66 and 68. Bus 68 may be grounded and bus 66 may be at plus 18 volts. Transistors 54 and 56 and the associated resistors are the inverting amplifiers 31 and 32 of FIG. 3. There is a third amplifier 51 including a transistor 52 at the input of circuit 40 which provides a constant input impedance and makes the input impedance of circuit 40 high enough so that it does not adversely load down the circuitry from which the input signals are supplied. Transistor 52 has a split load constituted by resistors 58 and 60 connected respectively in the collector and the bases of the transistors. Positive bias for the base of transistor 52 is derived from the junction 63 between resistors 62 and 64 connected in series as a voltage divider across the power supply buses 66 and 68. Similarly, transistor 54 has split load resistors 70 and 72 and transistor 56 has split load resistors 74 and 76. Positive bias being applied to the bases of the latter transistors by resistors 78 and 80 which form one voltage divider and resistors 82 and 84 which form another voltage divider.

Variable filter 28 includes a single capacitor 86 and a resistor 88 connected in series between the collector of transistor 52 and grounded bus 68. Filtered voltage appearing at the junction 89 between capacitor 86 and resistor 88 is applied to the base of transistor 54 by a coupling capacitor 90. The other variable filter 30 includes capacitor 92 and resistor 94 connected in series between the collector of transistor 54 and grounded bus 68, the junction 95 between capacitor 92 and resistor 94 being coupled to the base of transistor 54 by capacitor 96.

Filters 28 and 30 are of the high-pass type, but it is to be understood that low-pass filters may be used as an alternative by reversing the resistance and capacitance elements. Such filters may also be constructed with an inductor and a resistor, or an inductor and a capacitor. Inductors have been avoided in practice because for audio frequency filters they are too large and weighty. An advantage of resistance-capacitance filters is that the variable element, either the resistor or the capacitor may be grounded at one end. Where the variable elements are resistances like 88 and 94 in FIG. 3, they have a grounded connection (bus 68) between them and this makes it especially convenient to use a single integrated resistor which has two resistance arms (88 and 94) with a central tap which can be grounded. If low-pass filters are used in which the variable elements are ganged capacitors with a common plate, the common plate may be grounded.

The three signals to be summed are derived from the collectors of transistors 52, 54 and 56 by resistors 98, 100 and 102. The latter resistors are connected together at a point 104 and their current is connected to an output summing resistor 104. The other ends of resistors 98, 100 and 102 are connected respectively to the collectors of transistors 52, 54 and 56. As mentioned previously, the three signals which are summed in the summing network 35 should be weighted in amplitude according to the ratio of one part of input signal to four parts of the filtered signals in order to produce pure vibrato in the output signals appearing across terminals 48 and 50. By making the overall gain of circuit 40 unity, the desired summing ratio can be obtained by simply connecting the values of resistors 98, 100 and 102 to the ratio of 1:4:4. If the overall gain of circuit 40 is other than unity, the values of resistors 98, 100 and 102 may be adjusted accordingly to obtain the desired amplitude ratio.

If the three signals fed to summing network 35 are weighted in some ratio other than 1:4:4, or if the time constants of the two filters 28 and 30 are not equal, the tremolo is produced as well as vibrato; i.e., the output signal across resistor 104 will vary both in frequency and amplitude. In FIG. 3, resistor 98 has been made variable to provide the proper ratio to thereby determine the vibrato and tremolo content of the output signal.

The variable resistors 88 and 94 in filters 28 and 30 are light dependent resistors which can be modulated by illumination from a lamp 108 operated by the control device 27. As the intensity of lamp 108 varies, the values of resistors 88 and 94 vary to alter the time constants of filters 28 and 30 and thereby vary the phase of the signals appearing across resistors 100 and 102 relative to the signal across resistor 98. This dynamic phase variation produces vibrato in the output signal appearing across resistors 104.

The rate of the modulation is determined by component values in the control device 27. In the embodiment of FIG. 3, the control device is a phase shift oscillator including three transistors 110, 112 and 114 each having a split load. The split load of transistor 110 consists of resistors 118 and 120, and the split load of transistor 112 consists of resistors 122 and 124. Capacitor 126 and resistor 128 are connected in series from the collector of transistor 112 to its emitter, and the junction 127 between capacitor 126 and resistor 128 is connected to the base of transistor 110. At the frequency of the resistance of capacitor 126 equals the resistance of resistor 128, the phase shift from the collector of transistor 112 to the base of transistor 110 is minus 90°. Resistor 130 and capacitor 132 are connected in series from the collector of transistor 110 to its emitter, and the junction 131 is connected to the base of transistor 112. At the frequency where the resistance of resistor 130 equals the reactance of capacitor 132, the phase shift from the collector of transistor 110 to the base of transistor 112 is plus 90°.

Transistors 110 and 112 each produce a phase shift of 180°. Due to the opposite direction of the phase shifts produced by the two resistance-capacitance networks which cross couple the transistors, the total loop phase shift is 360° which is the condition necessary to sustain oscillations. Thus, the circuit will oscillate only at the frequency where the capacitance reactance of capacitors 127 and 128 is equal to the resistance of resistors 128 and 130.

Two signals taken from the amplifiers formed by transistors 110 and 112 with their split loads are combined by a resistor 133 and a capacitor 134 connected from the junction between resistors 116 and 118 to ground. The other end of resistor 133 is connected to a positive power supply terminal 136. A circuit branch connected from the power supply terminal 136 to ground includes a transistor 114 with its base connected to the emitter of transistor 112, a lamp 108 and resistors 138 and 140. The oscillating wave appearing at the emitter of transistor 112 drives the base junction 116 of transistor 114 connected to the output summing resistor 104 of the lamp 108. The varying light from lamp 108 in turn varies the resistance of resistors 88 and 94 to modulate the frequency of the signals passed by circuit 40.

The two light dependent resistances 88 and 94 may be integrated in a single light dependent resistor 142 as shown in FIG. 5. Light dependent resistor 142 has one arm 88 between terminals 146 and 148 and another arm 94 between terminals 146 and 148. Terminal 146 is a
center tap which may be connected to grounded bus 68 in FIG. 3. The resistance element consisting of arms 88 and 94 is made of a photoconductive material such as cadmium sulphide. By using a single light dependent resistor having two arms and a center tap, the values of the two arms may be made equal and will track each other accurately as their resistance values are varied by light from a single source.

FIG. 6 illustrates a simple manner of mounting a lamp 108 on the transparent face of light dependent resistor 142 and encapsulating this assembly with opaque plastic material 149 so as to keep ambient light from affecting the light dependent resistor 142.

FIG. 4 shows the circuitry of another embodiment of the invention. Like components in FIGS. 3 and 4 have the same reference numerals. In circuit 150, there is an input amplifier 51, two intermediate amplifiers 31 and 32 and an output amplifier 167 which is part of the summing network 35. The first high-pass filter 28 between amplifiers 31 and 32 consists of a capacitor 86 and a light dependent resistor arm 88 connected in series from the emitter of transistor 52 to grounded bus 68. The second high-pass filter 30 consists of capacitor 92 and light dependent resistor arm 94 connected in series from the emitter of transistors 54 to grounded bus 68. Filters 28 and 30 are coupled to the bases of transistors 54 and 56 respectively by capacitors 90 and 96.

There is a switch having two ganged movable contacts 156 and 158 in filters 28 and 30 respectively. When movable contacts 156 and 158 are in the upper position as shown, the high-pass vibrato filters 28 and 30 are in circuit with the inverting amplifiers 31 and 32 and may be varied by cyclically illuminating resistance arms 88 and 94 to produce vibrato in the output signals. When movable contacts 156 and 158 are in their lower positions, filter 30 is disconnected from amplifier 32, so filter 30 and amplifier 32 have no effect on the signals passing through circuit 150. Resistor 155 remains in circuit with capacitor 92 and serves to hold that capacitor at the same potential so that there will be no clicking noise in the sound from the system (FIG. 1) when contact 158 is switched back to the upper position. Resistors 157 and 161 likewise hold capacitors 86 and 96 at a given potential to prevent clicking when contact 156 is switched.

With movable contact 156 in its lower position filter 28 produces no phase shift because of the large value of resistor 157 in series with capacitor 86. Resistor 162 is connected in series with light dependent resistor arm 88 forming a resistive voltage divider which is varied by cyclically illuminating this arm. Filter 28 does not respond to resistor 162 and couples the emitter of transistor 52 to the resistor 162 and has a sufficiently large value that there is no phase shift in this signal path. Thus, the signals passing through the circuit are varied only in amplitude producing a tremolo effect in the output. Note that in this case, only two signals are combined in the summing network formed by resistors 98, 100 and 102 together with transistor 168 and its emitter resistors 172 and 174. The first signal is the amplified input signal supplied through resistor 98, and the second signal is a further amplified version of the input signal supplied through resistor 100. These signals are out-of-phase and the sum varies in amplitude at a rate determined by the control device 181.

The remainder of circuit 150 is similar to circuit 40 of FIG. 3, but some of the interconnections differ slightly. The input terminal 24 is connected to the base of transistor 52 which in this embodiment is connected as an emitter follower, the collector of which is connected to grounded bus 68 and the collector of transistor 52 being connected directly to the positive power supply bus 66. Resistor 152 connected from the base of transistor 52 to positive bus 66 biases the base positively, and capacitor 153 connected to the base of transistor 52 together with a capacitor connected to the collector of transistor 168 limit the high frequency response of circuit 150 to four kilocycles. The latter capacitors are not essential, but since there are no signal frequencies above four kilocycles except noise, the above frequency limiting noise in the output. Resistor 154 simply drops the supply voltage appearing at terminal 186 to an appropriate level.

Transistor 54 has split-load resistors 70 and 72 as in FIG. 3 and a base bias resistor 159. Transistor 56 is connected as an emitter follower, and has an emitter resistor 175 and a base biasing resistor 177. Transistor 168 has resistors 172 and 174 in its emitter path and resistor 170 in its collector path, and its base is connected to the three summing resistors 98, 100 and 102. Capacitor 176 bypasses resistor 174 for audio frequencies. Capacitor 178 decouples the collector of transistor 56 from power supply bus 66 for audio frequencies to keep audio signals out of the power supply. Output signals are supplied to terminal 26 through coupling capacitor 179 connected to the collector of transistor 168.

The control device 181 for the embodiment of FIG. 4 is of a type which provides a sawtooth wave for energizing the lamp 108. Control device 181 includes a positive power supplying bus 182 connected through resistor 184 to the power supply terminal 186. Supply bus 188 is grounded. The operating voltage is regulated by a Zener diode 190 connected between busses 182 and 188. The control device is turned on by closing switch 192 to connect the base of transistor 194 to ground potential.

Transistors 194 and 196 are interconnected so as to form a multivibrator circuit which is free-running when switch 192 is open. The collector of transistor 196 is cross-coupled to the base of transistor 194 by capacitor 198 and the collector of transistor 194 is cross-coupled to the base of transistor 196 by capacitor 200. Resistors 202 and 204 are connected respectively from the collectors of transistors 194 and 196 to the positive bus 182 and provide load resistors for the transistors. Resistor 206 connected from the base of transistor 194 to bus 182 polarizes the base of the transistor positively, and series resistors 208 and 210 connected from the base of transistor 196 to bus 182 polarizes the base of the latter transistor positively.

Transistors 194 and 196 alternate between on and off conditions providing a substantially sawtooth voltage at the base of transistor 196. The latter voltage is modified by capacitor 217 and resistors 212 and 214 to provide a sawtooth driving voltage at the base of transistor 216. The emitter portion of the latter transistor clamps the base of the output transistor 218 at a positive potential which provides a threshold voltage. Specifically, transistor 218 and the sawtooth voltage applied to transistor 216 rises above the threshold voltage. This threshold, then, determines the minimum light level produced by lamp 108.

Operating potentials for transistor 218 are furnished by resistors 220, 222, 224, 226 and 228. Resistor 218 connected to transistor 196 may be varied to control the repetition rate of device 181. This in turn controls the rate of vibrato or tremolo. Resistor 220 may be varied to control the depth of vibrato or tremolo.

The reason for energizing lamp 108 with a sawtooth wave is to allow for a difference between the rise time and fall time of the lamp. When using a sawtooth waveform, the lamp is easy to ignite when the lamp is unlit, and it is useful for the leading edge of the sawtooth wave, but the rate at which it dims is independent of the trailing edge of the wave. In FIG. 7, the sawtooth waveform 230 represents the energizing signal for lamp 108, and the more nearly sinusoidal waveform 232 represents the illuminating current corresponding to the resistance variation of the light dependent resistor arms 88 and 94. Thus, by using a sawtooth drive for the lamp, it is possible to obtain a fair approximation to a sinusoidal variation of the light dependent resistor which produces a desirable vibrato effect in the output signals from the vibrato circuit.

The following values and type identification for the
components used in the circuit of FIG. 4 are given by way of example only and are not to be construed as a limitation on the scope of the invention:

All transistors: 2N2926.

Resistors:

- 70, 72, 151, 175: 390 ohms.
- 162: 10 kilohms.
- 88 and 94: Dual L.D.R. (Clairtex).
- 98: 16 kilohms.
- 100, 9: 3.9 kilohms.
- 172: 68 ohms.
- 170: 1.8 kilohms.
- 174: 3.3 kilohms.
- 206: 220 kilohms.
- 202, 204: 10 kilohms.
- 208: 100 kilohms.
- 212: 430 kilohms.
- 214: 560 kilohms.
- 222: 4.7 kilohms.
- 224: 10 kilohms.
- 226: 47 ohms.
- 184: 390 ohms.
- 154: 1 kilohm.

Capacitors:

- 198, 200, 217: 1.0 microfarad.
- 153: 0.01 microfarad.
- 86, 92, 179: 22 microfarad.
- 160: 10 microfarads.
- 90, 96: 0.1 microfarad.
- 180: 0.2 microfarad.
- 176: 20 microfarads, 50 v.
- 178: 100 microfarads, 25 v.
- Diode 190: 1 watt Zenet, 12 v.
- B-plus voltage: 39.5 ± 5 v.

FIGS. 8 and 9 illustrate graphically the relationship between phase angle and frequency produced by the circuits of FIGS. 3 and 4 when operating in the pure vibro mode. In FIG. 8, frequency is plotted against phase angle and in FIG. 9, log frequency is plotted against phase angle. The formula corresponding to these curves is:

\[ \phi = 4 \tan^{-1} \frac{RC}{2} \]

From the formula it is apparent that by varying either R or C, it is possible to vary the phase angle of a signal passing through the network. The effect of the resistance or capacitance variation is to shift the curves as shown by the dashed lines in FIGS. 8 and 9. The amount of vibro corresponds to the slope of the curve of FIG. 8 at any given frequency. From the curve, it is evident that vibro is a maximum at lower frequencies and decreases with increasing frequency. The decrease is fairly gradual, however, and there is sufficient vibro at relatively high frequencies to produce a proper vibro effect.

The all-pass characteristics of the circuits of FIGS. 3 and 4 may be explained mathematically as follows. The transfer function for an all-pass filter is given by the formula:

\[ \frac{T_{S} - 1}{T_{S} + 1} \]

where

\[ T = RC \]

\[ S = I_0 \]

Where two stages are cascaded as in the circuits of FIGS. 3 and 4, the transfer function is given by:

\[ \frac{(T_{S} - 1)^2}{(T_{S} + 1)^3} \]

The latter function can be expanded to:

\[ \frac{4}{T_{S} + 1} + \frac{4}{(T_{S} + 1)^3} \quad \text{or} \quad 4 \frac{T_{S}}{T_{S} + 1} + 4 \frac{(T_{S} - 1)^2}{(T_{S} + 1)^3} \]

Referring to FIG. 2, the first term of this formula determines the amount of the input signal fed to summing network 35. The second term in the formula shows that a second signal, which is shifted in phase relative to the input signal, is summed with the input signal. The subtraction indicated by the minus sign is accomplished in FIG. 3 by the phase inverter from base to collector of transistor 54 and in FIG. 4 by taking the second signal to be summed from the collector of transistor 54 whereas the signal fed to transistor 56 is taken from the emitter of transistor 54. The third term in the formula corresponds to the second filtering and amplifying stage. The summing ratio is determined by the numerators of the terms of the formula; i.e., 1, 4 and 4.

The invention provides an all-pass system capable of introducing vibro into signals varying over a very wide range of frequencies without attenuating any frequency or with some constant attenuation of all frequencies. The system has a flat frequency response at least over the entire range of signal frequencies and can vary the phase of the signals in any amount up to 360°. Tremolo may be added to the vibro if desired, or the system can be set by means of switches to produce pure tremolo. From FIGS. 3 and 4, it is apparent that by using a light dependent resistor as the variable element for introducing a dynamic phase shift, the control signals may be completely isolated from the filtering and amplifying circuit. If such control signals were allowed to pass to the output system of the musical instrument they would cause an objectionable rumbling sound, and filtering would be necessary to remove them from the output.

I claim:

1. A vibro system for an electrical musical instrument comprising first and second phase-shifting stages each having an input and an output, means coupling the output of said first phase-shifting stage to said input of said second phase-shifting stage to interconnect said stages in cascade relation, a signal input coupled to said output of said second phase-shifting stage, each of said phase-shifting stages including a filter network having a variable impedance means therein, summing circuit means having an output and at least three inputs connected respectively to said signal input and to said outputs of said first and said second phase-shifting stages for producing an output signal at said output of said summing network, and means for cyclically varying said variable impedance means in unison at a predetermined ratio to thereby vary said output signal in frequency at said vibro rate.

2. A vibro system for an electrical musical instrument comprising first and second phase-shifting stages each having an input and an output, means coupling the output of said first phase-shifting stage to the input of said second phase-shifting stage, a signal input coupled to the input of said first phase-shifting stage, each of said phase-shifting stages including variable impedance means for varying the phase angle of a signal in said stages, a summing network having an input and including impedances connected respectively to said signal input and to the output of said first and second phase-shifting stages for combining signals supplied therefrom in a predetermined ratio to produce an output signal at said output of said summing network, and means for cyclically varying said variable impedance means at a predetermined vibro rate to thereby modulate said output signal in frequency at said vibro rate without introducing substantial amplitude modulation therein.

3. A vibro system for an electrical musical instrument comprising first and second phase-shifting stages each having an input and an output, means coupling the output of said first phase-shifting stage to the input of said second phase-shifting stage and interconnecting said stages in cascade relation, a signal input coupled to the input of
said first phase shifting stage, each of said phase shifting stages including a filter network and an amplifier serially connected between the input and output of said stage, said filter networks each having variable impedance means therein, a summing network having an output and including impedances connected respectively to said signal input and to the outputs of said first and second phase shifting stages for combining signals supplied theretofrom in a predetermined ratio to produce an output signal at the output of said summing network, and means for cyclically varying said variable impedance means in unison at a predetermined vibrato rate thereby said output signal in frequency at said vibrato rate.

4. The vibrato system of claim 3 in which said variable impedance means comprises a light dependent resistor, and said varying means comprises a lamp for illuminating said light dependent resistor and control circuit means for cyclically varying the intensity of light from said lamp.

5. The vibrato system of claim 4 in which said light dependent resistor has a first resistance arm in the filter network of said first phase shifting stage and has a second resistance arm in the filter network of said second phase shifting stage.

6. The vibrato system of claim 5 in which said filter networks are of the resistance-capacitance type.

7. The vibrato system of claim 3 in which said control circuit means includes a multivibrator circuit, and means coupled to said lamp and to said multivibrator circuit and energized by said multivibrator circuit to drive said lamp with a sawtooth wave to light and dim said lamp at substantially the same rate.

8. The vibrato system of claim 3 further including switching means for disconnecting said filter networks and for connecting at least one of said variable impedance means in circuit between the input and output of the respective phase shifting stage, thereby converting said vibrato system into a tremolo system.

9. The vibrato system of claim 3 in which at least one of the impedances of said summing network is variable to change said summing ratio and thereby produce tremolo as well as vibrato in the output signal.

10. A vibrato system for an electrical musical instrument having a source of audio frequency signals comprising first and second variable phase-shifting stages each having an input and an output, a signal input adapted for connection to said source of audio frequency signals and being coupled to said input of said first phase-shifting stage, first circuit means coupling said output of said first phase-shifting stage to said input of said second phase-shifting stage, summing circuit means having an output and at least first, second and third inputs and adapted to provide an output signal representing a predetermined summing ratio between signals applied to said first, second and third inputs, second circuit means coupling said signal input to a first input of said summing circuit means, third circuit means coupling said output of said first phase-shifting stage to a second input of said summing circuit means, and fourth circuit means coupling said output of said second phase-shifting stage to a third input of said summing circuit means, said summing circuit means having its predetermined summing ratio correlated to the amplitudes of signals at said first, second and third inputs such that said output signal represents substantially one part of said audio frequency signal to four parts of said audio signal as modified by said first phase-shifting stage and four parts of said audio signal as further modified by said second phase-shifting stage, and control means for varying said phase-shifting stages substantially in unison to produce a dynamic phase shift in said stages and thereby frequency modulate said output signal.

11. The vibrato system set forth in claim 10 wherein each of said phase-shifting stages comprises phase inversion circuit means and a variable filter network having a variable impedance means therein and wherein said control means is operatively coupled to each of said variable impedance means in said first and said second phase-shifting stages to vary said impedance means in each stage substantially in unison.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,413,403

Keith D. Jacob

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 31, "These" should read -- There --. Column 7, lines 72 to 74, at the beginning of the formula and before the minus sign insert the numeral -- 1 --. Column 9, line 27, the claim reference numeral "3" should read -- 4 --.

Signed and sealed this 17th day of March 1970.

(SEAL)
Attest:
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Commissioner of Patents