Aug. 25, 1964

D. L. BONHAM

3,146,292

ELECTRICAL VIBRATO AND TREMOLO DEVICES

Filed March 8, 1954

3 Sheets-Sheet 1

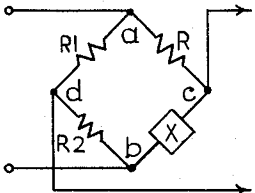

FIG. 1

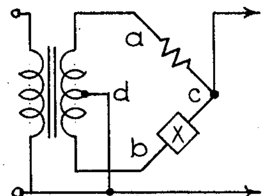

FIG. 2

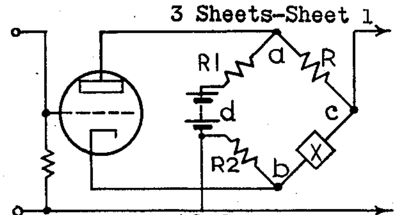

FIG. 3

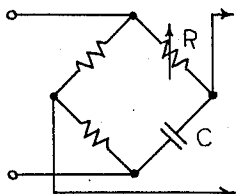

FIG. 4

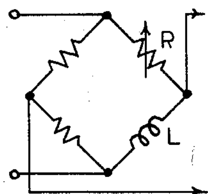

FIG. 5

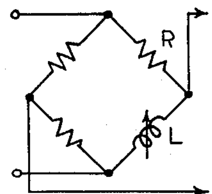

FIG. 6

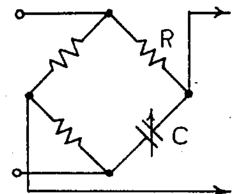

FIG. 7

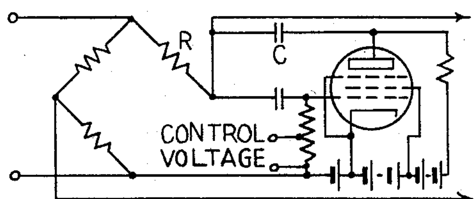

FIG. 8

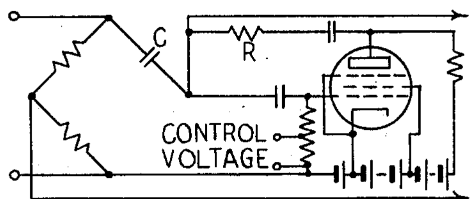

FIG. 9

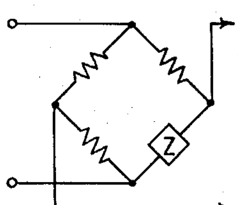

FIG. 10

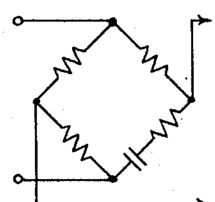
FIG. 11

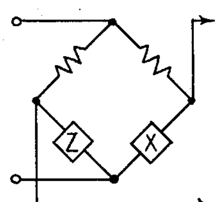

FIG. 12

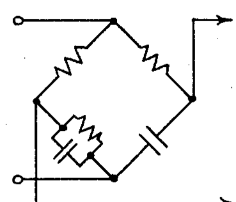
FIG. 13

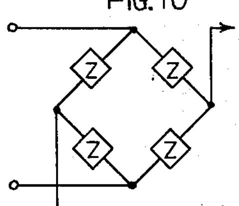

FIG. 14

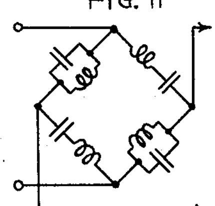
FIG. 15

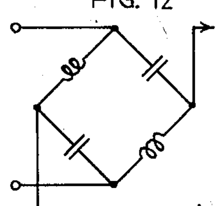
FIG. 16

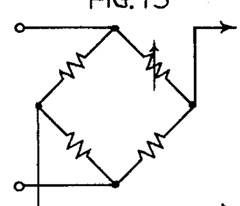
FIG. 17

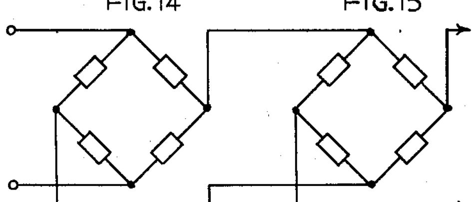
FIG. 18

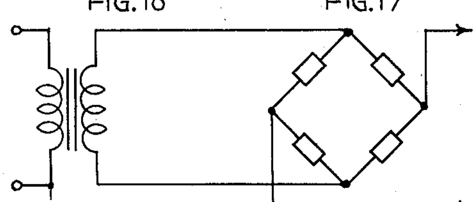
FIG. 19

INVENTOR.

D. L. Bonham

ELECTRICAL VIBRATO AND TREMOLO DEVICES

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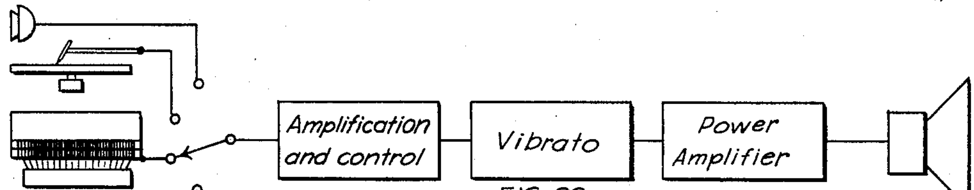

FIG. 20

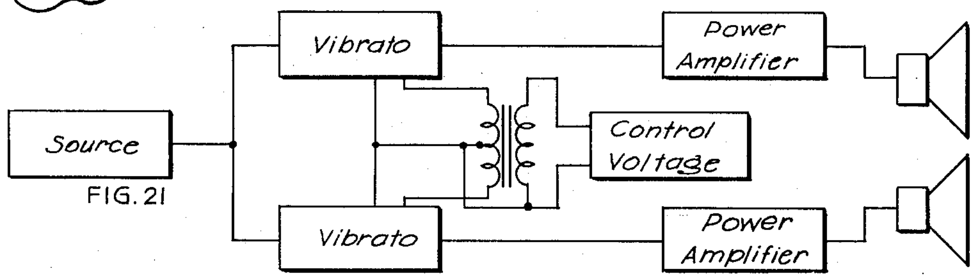

FIG. 21

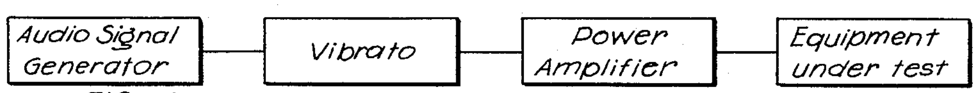

FIG. 22

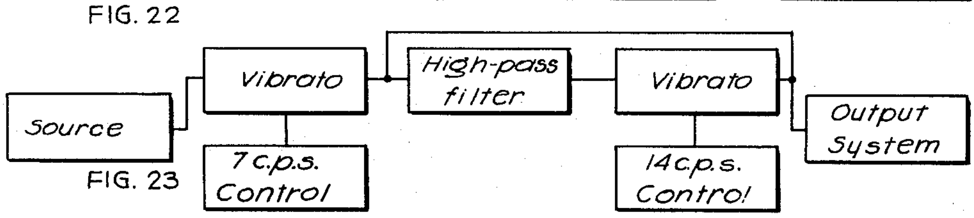

FIG. 23

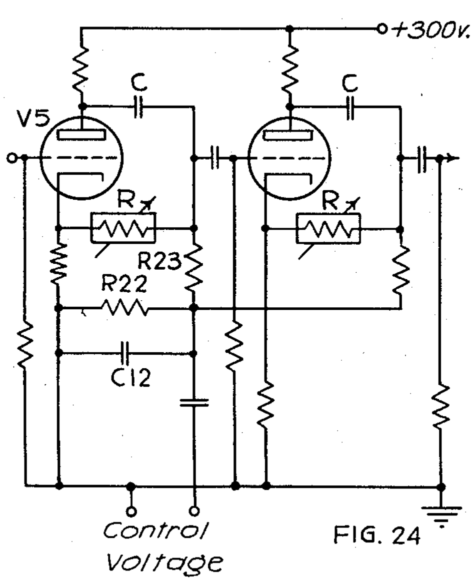

FIG. 24

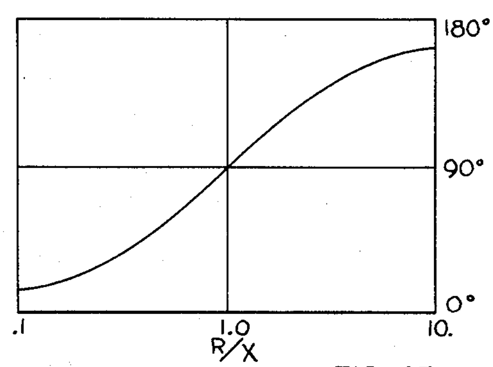

FIG. 25

INVENTOR.

D. L. Bonham

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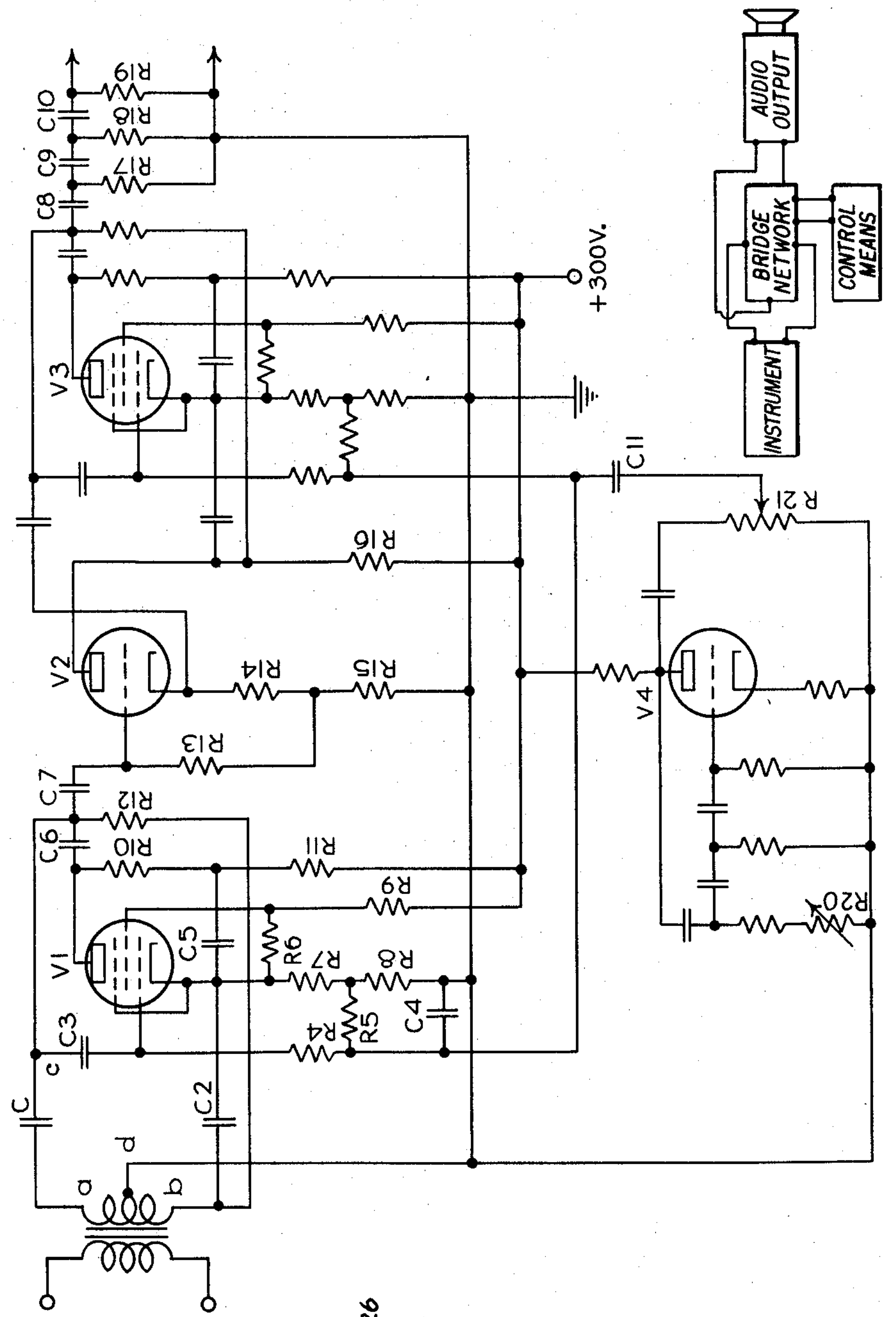

FIG. 27

FIG. 26

INVENTOR.

D. L. Bonham

United States Patent Office

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3,146,292
ELECTRICAL VIBRATO AND TREMOLO DEVICES

Don L. Bonham, 1224A Orange Grove Ave., Glendale, Calif.

Filed Mar. 8, 1954, Ser. No. 414,589
12 Claims. (Cl. 84—1.25)

My invention relates to the production of cyclic variation in frequency or amplitude of audio frequency electrical signals. These variations are termed "vibrato" when the variations are predominantly of frequency, and "tremolo" when the variations are predominantly of loudness. The usual rate of variation is within four to eight cycles per second, but for some purposes may be of much lower or higher rate; lower than one per second, or higher than thirty per second. The terms "vibrato" and "tremolo" will be used herein, regardless of rate, to denote the predominant nature of the variation.

The magnitude of the variation of frequency or amplitude above and below mean values also may be considerable. In music, vibrato of five percent of mean frequency is common, and vibrato for acoustical testing purposes may be much greater. Tremolo, especially when the pitch of the signal is relatively high, may be one hundred percent of mean amplitude.

In some musical instruments, vibrato is produced by generating the desired frequency variations at the initial source, as is the case with the human voice, the slide trombone, and stringed instruments in which pitch is determined by the position of the finger on the string or the position of a slide. In other instruments, such as some electric organs and the piano, containing little or no natural vibrato, vibrato may be added by any of a number of means, some based on the Doppler Principle and others based on variation of the velocity of propagation of the transmitting system or medium.

Briefly, the Doppler Principle points out that apparent frequency depends on the relative motion of the source and the observer. Examples of this means of obtaining a vibrato are found in acoustical devices in which the source of sound or the observer is cyclically moving, as a rotating loudspeaker or deflector, or a fixed loudspeaker and moving microphone. Another means based on the Doppler Principle consists of transmitting signal currents through a system incorporating time delay, such as an artificial transmission line or wave filter consisting of inductance and capacitance, and scanning with a pickup means along the artificial transmission line, varying its effective length.

An example of a vibrato system utilizing varying velocity of propagation is that in which the electrical currents are transmitted through a wave filter whose components are varied in magnitude at vibrato rate.

Both of these methods of adding vibrato to a signal employ the following principle. When a signal of fixed frequency is transmitted through a medium to an observer, variation of either the velocity of propagation or the path length of the medium will result in a deviation of the frequency of the received signal, since, in either case, the number of cycles in transit in the medium will be changed, thus changing the number of cycles per unit time arriving at the observer. Because increasing or decreasing the number of impulses in transit between the source and the observer results in retarding or advancing the phase of the received signal relative to the transmitted signal during the increase or decrease, it is convenient to regard the effect of changes in the medium in the light of the phase shift they produce. The magnitude of frequency deviation obtained will be proportional to the rate of change of phase and the amount of phase shift. It is thus a dynamic system, since change in the amount of phase shift, not the absolute amount of phase shift encompassed by the system, results in frequency deviation.

It is the object of this invention to add vibrato or tremolo, or both, to any electrical signals produced by, or intended ultimately to produce, sound, regardless of the source, and to any signals employed in the testing of apparatus used in connection with the transmission or recording of audio frequencies; and to provide a new means of obtaining vibrato or tremolo or both without the use of artificial transmission lines, wave filters, or acoustical devices.

Preferred forms of this invention use no moving parts. It may be operated as either a Doppler or variable velocity of propagation device. Using simple and practical circuits and components, it provides readily controllable vibrato or tremolo or both of any desired intensity and rate, and provides an unusually large amount of the desired effect per circuit element.

Preferred forms of this invention use no inductors, thus avoiding undesirable bulk, weight, cost, resonances, and magnetic field coupling. Since no artificial lines or wave filters are used, there can be no reflections or distortion caused by impedance mismatching or variations of the values of circuit components.

In order to obtain the phase shift necessary for a dynamic vibrato system, this invention utilizes a bridge or lattice network. The expressions "bridge" and "lattice" refer to the same basic circuit. The preferred expression customarily depends on the means of graphical representation employed. The bridge representation is used in this application for convenience. The term "bridge" refers to the type of network in which a source of electrical current is applied across two paralleled branches, each consisting of two or more elements connected in series, with the input coupled to the ends of the paralleled branches, and the output coupled between junction of elements in the two branches.

FIG. 1 is a schematic diagram of a constant-attenuation type of bridge using three resistive arms and one reactive arm.

FIGS. 2 through 9 are various embodiments of the basic resistance-reactance bridge.

FIGS. 10 through 13 are modifications of the basic resistance-reactance bridge.

FIGS. 14, 15, and 16 are diagrams of non-attenuating inductance-capacitance bridges.

FIG. 17 is an all-resistance tremolo bridge.

FIGS. 18 and 19 depict bridge coupling methods.

FIGS. 20 through 23 are block diagrams illustrating applications of this invention.

FIG. 24 is the schematic diagram of an embodiment of this invention using varistors, thermistors, or other voltage-sensitive or temperature-sensitive resistors.

FIG. 25 is a graph of the phase shift obtained in the resistance-reactance bridge.

FIG. 26 is the schematic of a preferred form of the invention.

FIG. 27 is a schematic box diagram showing the manner of connecting the device of the present invention in any musical instrument.

An appropriately designed bridge will transmit all frequencies with constant attenuation versus frequency, and will produce phase shift approaching one hundred and eighty degrees, using only resistive and capacitive elements. A bridge of this type is illustrated in FIG. 1. The arms R1 and R2 of branch *adb* represent a means of obtaining from the signal source two voltages generally, but not necessarily, substantially equal in amplitude and opposite in phase about a common reference point. Any other means, such as transformers, FIG. 2, or vacuum tubes, FIG. 3, both of which offer the advantage of a connection common to both input and output, may be used to obtain the desired voltages without changing the principle involved. In each illustration, arm R represents a resistance and arm X represents either a capacitive or inductive reactance. C represents capacitance, and L, inductance. When an alternating voltage of any frequency is applied between points *a* and *b*, a voltage appears between points *c* and *d* equal to approximately one half the applied voltage and shifted in phase by an amount dependent on the ratio of R to X. The use of a vacuum tube, as shown in FIG. 3, also serves to offset the loss of signal in the bridge circuit. FIG. 25 depicts the magnitude of phase shift produced versus the ratio of R to X. Varying element R or X through suitable values at the desired rate varies the amount of phase shift produced by the bridge, resulting in the addition of vibrato to the transmitted signal.

In FIGS. 4 and 5, the varying elements is a variable resistor, such as a motor driven rheostat, a series of fixed resistors selected by a sequence mechanism, or a varistor, thermistor, or other voltage, current, or temperature sensitive resistance.

In FIG. 6, the varying element is a variable inductor, such as a saturable reactor, a coil with taps selected by a sequence mechanism, a coil with a moving core, or a motor driven variometer.

In FIG. 7, the varying element is a mechanically varied capacitor, such as a motor driven rotor-stator capacitor or a series of fixed capacitors selected by a sequence mechanism.

In FIG. 8, the varying element is a variable electronic reactance tube modulated by means of a vibrato frequency control voltage derived from any convenient source, such as a vacuum tube oscillator.

In FIG. 9, the varying element is a vacuum tube operated so as to function as a variable resistor. This embodiment is fully described later as a preferred form of the invention.

FIGS. 1 through 9 all represent simple cases in which substantially pure resistive or reactive elements are used in each arm of the bridge. In each case, however, desirable effects may be obtained by adding resistance to a reactive arm, or reactance to a resistive arm. Also, both capacitive and inductive reactances, with or without resistance, may be combined in one or more arms.

In the following figures, the symbol Z represents an impedance composed of any combination of resistance, capacitance, and inductance. FIG. 11 is a version of the general case represented in FIG. 10, in which resistance has been added in series with a capacitive arm, producing tremolo in the output of the bridge which tends to increase with increasing signal frequency.

FIG. 13 is a version of the general case represented in FIG. 12, in which a capacitive reactance is paralleled across a resistive arm in order to produce a phase shift which tends to compensate for the curvature of the function depicted in FIG. 25 where the ratio of R to X becomes relatively large. This has the effect of increasing the vibrato and producing tremolo at the higher frequencies.

FIG. 15 is a version of the general case represented in FIG. 14, in which each arm is a combination of inductive and capacitive reactance. This bridge produces approximately twice the amount of phase shift produced by the simpler bridges and has no attenuation. The varying elements could be either the inductance or the capacitance. FIG. 16 represents a bridge having no attenuation and a maximum of one hundred and eighty degrees of phase shift. Variable elements could be either the inductance or the capacitance.

FIG. 17 represents a bridge which produces tremolo, only, through variation of the value of the resistance of any arm.

FIG. 18 depicts a general means of coupling one bridge

into another. In this arrangement, it is desirable that the second bridge have a characteristic impedance several times that of the first. Transformer, FIG. 19, makes available a connection common to both input and output circuits, as shown by the dotted line.

The block diagram of FIG. 20 illustrates a few specific examples of the application of this invention, where the source of signals is a microphone, a phonograph pickup or tape reproduction machine, an electric organ, or an acoustic instrument with an electrical pickup; and where, after passing through the vibrato and/or tremolo, suitable amplification, and control, the impulses are applied to a loudspeaker. The output of the system might equally well be coupled directly to recording or broadcasting equipment.

FIG. 22 illustrates an application of this invention for testing purposes, in which the output of a signal generator is transmitted through the vibrato invention in order to present to the apparatus under test a signal which varies about a mean frequency. This is useful in cases such as loudspeaker testing, where, in conjunction with measuring instruments of relatively heavy damping, it serves to average out sharp peaks and dips in response which interfere with measurement of general response.

The flexibility of this means of producing vibrato makes it relatively simple to obtain many effects which are otherwise extremely difficult or impossible to obtain. For example, in musical instruments using the same series of sine function tone generators tuned to the tempered scale for both fundamentals and overtones of synthesized complex tones, the tone quality, particularly in the upper registers, tends to be dull, due to the lack of the beat frequencies normal to natural-harmonic instruments. In order to minimize this effect, the higher frequencies of the instrument, above fifteen hundred cycles per second, for example, may, in addition to the basic rate vibrato, have applied to them an additional vibrato of higher rate, such as two, three, or four times basic. This high rate, which would be objectionable if applied to the lower tones, sounds pleasing on higher tones and is perceived, not so much as a fast vibrato, as a combination of the original frequency plus complex side bands. An additional advantage of a high vibrato rate is that, since the amount of vibrato obtained is directly proportional to the rate of the vibrato, a multiple rate results in an amount of vibrato per circuit element that is increased by the same factor. FIG. 23 illustrates an arrangement of this type.

FIG. 21 depicts a combination of two vibrato channels coupled to the same source and controlled in opposite vibrato phase, so that, while one is advancing the phase of transmitted signals, the other is simultaneously retarding it. This tends to reduce the effect of wandering pitch sometimes heard when tones are sounded briefly with respect to a vibrato cycle, and, also, results in complex side-bands which may be desirable, as in the previous example. For the purpose of illustration, FIG. 21 depicts vibrato channels utilizing electronic control, with one hundred and eighty degrees of difference in phase of control voltages obtained through the use of a center-tapped transformer. However, any other arrangement of elements and control means could produce the same result, so long as the two channels produce opposite vibrato phase. A number of vibrato channels operated in this way, with a vibrato phase separation preferably equal to three hundred and sixty degrees divided by the number of channels, produce, in proportion to the number of channels, minimizing of vibrato periodicity and maximizing of side-bands.

The selection of the values of the elements of the bridge should be such that the bridge will not load the source with an excessively low impedance at any point in the range of excursion of the variable element or elements at any frequency which is to be transmitted, unless tremolo is desired and the nature of the source is such that distortion will not result. The impedance of the output circuit loading the bridge should be several times the impedance of the bridge. Since each arm of the bridge is effectively in series with the output circuit, its impedance should be low compared to the output circuit impedance.

Referring to FIG. 1, the ratio of R to X is generally made equal to unity at the highest frequency important in the particular application, with the variable element at its geometric mean value, in order that phase shift will increase, and vibrato be constant with frequency. This consideration is based on the fact that, for a constant vibrato versus frequency relation, the number of degrees of phase shift should bear a fixed ratio to signal frequency. As indicated in FIG. 25, with ratios higher than unity, phase shift tends to become constant with frequency. Vibrato, therefore, tends to decrease with frequency, although ratios considerably higher than unity are still useful.

As mentioned earlier, R1 and R2 are generally, but not necessarily, substantially equal in resistance. If pure vibrato is desired, equal values are indicated. If a combination of vibrato and tremolo is desired, however, the use of unequal values offers a convenient means of achieving it. In practical applications, a combination of both vibrato and tremolo is often more desirable than either, alone. It is the object of this invention to provide a means of producing both vibrato and tremolo, and either or both may be produced by the several arrangements herein disclosed, or by combinations of said arrangements.

FIG. 17 includes no reactive elements and produces pure tremolo through the variation of the resistance of any arm. Values of the arms are so selected that the desired amount of signal is transmitted with the control means in rest position, that is with the variable element stopped at its geometric mean value. Operation of the variable element will vary the output of the bridge above and below its output in rest position. Tremolo amplitude modulation may be upward, downward, or about a mean, and of any desired intensity.

In the design of the types of bridges shown in FIGS. 15 and 16, the same general consideration in respect to loading of the bridge and the source apply as in the case of the resistance-reactance bridge. The function of phase shift versus frequency may take many differing forms, but the selection of component values is chosen such that the rest point of the variable elements falls at a point corresponding to the inflection point of the curve in FIG. 25.

Control of the amount of vibrato or tremolo may be achieved by any of the many obvious means of controlling the range of excursion of the variable elements, or by selecting the appropriate number of bridges in a series. For most purposes, two or more bridges will be required to obtain the desired amount of vibrato. Multiple bridges may be operated in cascade, feeding from one bridge into another, or isolated by tubes or transformers or both. By the use of multiple bridges in cascade and controlled in unison, any amount of vibrato may be obtained. In the case of a sufficient number of cascaded bridges, it is possible to operate on the Doppler Principle by using fixed elements in the bridges and scanning from end to end of the series with a suitable pickup device.

FIG. 26 depicts a preferred form of the invention using two bridges in cascade, with the varying elements in the form of vacuum tubes controlled at vibrato rate by a vacuum tube oscillator and connected so as to function as variable resistors. In the first bridge, branch *adb* is a transformer, as in FIG. 2, and in the second bridge, it takes the form of the plate and cathode resistors of a vacuum tube V2, as in FIG. 3. In each bridge, the reactive element is a fixed value capacitor C. Located in each bridge, as in FIG. 9, is a remote-cutoff pentode vacuum tube with its cathode coupled through blocking capacitor C2 to bridge terminal *b*, and its plate and control grid coupled through blocking capacitors C6 and C3 to bridge terminal *c*. A relatively large vibrato-rate control voltage which serves to vary the grid-plate transconductance of the tube is applied to the control grid through R4. Since the blocking capacitors are so selected that their reactances are low compared to the associated resistances, plate current in the tube is in phase with grid voltage. Thus, voltages appearing between points *b* and *c* will produce an in-phase current through the tube, and arm *bc* will function as a resistance whose magnitude varies with the vibrato-rate control voltage. Direct current ground returns for the control tubes are through resistor R7, which develops grid bias, and R8, which is of sufficiently high value to avoid shunting bridge point *b* to ground. Screen voltage is supplied from a voltage divider composed of R6 and R9. Plate voltage is supplied through isolating resistor R11 and load resistor R10, with a plate to cathode return provided by capacitor C5.

The large vibrato-rate voltage which appears on the plate as a result of the control voltage applied to the grid is attenuated before being fed back to the grid circuit and into the output circuit by connecting from the junction of capacitors C6 and C7 back to bridge point *b* through resistor R12, whose value is low at control frequency compared to the reactance of capacitor C6.

The output of the first bridge is fed through capacitor C7 to the grid of vaccum tube V2, whose grid return resistor R13 is of sufficiently low value that, in combination with the reactance of C7, further attenuation of control frequency is obtained. Vacuum tube V2 functions as branch *adb* of the second bridge as the result of the signal voltages appearing across its plate resistor R16 and its cathode resistors R14 and R15. The second bridge is connected to succeeding apparatus through a high-pass filter composed of capacitors C8, C9, and C10, and resistors R17, R18, and R19, which attenuates control frequency and transmits signal frequencies. Although control frequency, generally around seven cycles per second, is too low to be audible, it could contribute to the overload of succeeding apparatus and should be attenuated to the point where the possibility is avoided.

The control voltage is derived from a phase shift oscillator. Rate is controlled by variable resistor R20, and intensity of vibrato is controlled by potentiometer R21, which determines the amplitude of control voltage applied to V1 and V3 through blocking capacitor C11. C4 avoids coupling V1 and V3 through their grid returns by bypassing signal frequencies to ground. Its reactance is sufficiently high at control frequency to avoid substantial loss of control voltage. Grid-to-cathode bias return for V1 and V3 is through R5.

Values of the components in FIG. 26 are in accordance with ordinary practice and the considerations set forth above. Representative values may be as follows: R4, 5 megohms; R5, 1 megohm; R6, .25 megohm; R7, .025 megohm; R8, .15 megohm; R9, 1 megohm; R10, .25 megohm; R11, .25 megohm; R12, .15 megohm; R13, .15 megohm; R14, 1500 ohms; R15, .01 megohm; R16, .01 megohm; R17, .5 megohm; R18, 1 megohm; R19, 2 megohm; C, .005 mfd.; C2, .1 mfd.; C3, .005 mfd.; C4, .02 mfd.; C5, .25 mfd.; C6, .005 mfd.; C7, .005 mfd.; C8, .01 mfd.; C9, .005 mfd.; C10, .0025 mfd.; C11, .05 mfd. V1 and V3 may be type 6BJ6, and V2 and V4, the two halves of a 12AX7.

FIG. 24 is also a version of the invention using two bridges in cascade with variable resistive elements. In this case, the resistive elements are voltage-sensitive units known as varistors, or temperature-sensitive units known as thermistors. In either type, a control voltage which is large relative to signal voltages is applied across the sensitive element, causing its resistance to vary. Control voltage is applied through isolating resistor R23. R22 completes a direct current path so that part of the voltage developed across the cathode resistor of V5 is applied across the sensitive element, causing a direct current to flow through it. This biasing current determines the way in which the resistance of the sensitive element varies with control voltage. In the absence of biasing current, the variation of resistance will be at twice the frequency of the applied control voltage. C12 bypasses signal voltages to ground to avoid undesirable bridge-to-bridge coupling through the control circuit.

FIG. 27 shows a general arrangement, in schematic form, for use of the present invention with a musical instrument or the like. In the figure the box labelled "INSTRUMENT" is arranged with its signal output connected to the input of the bridge network, the output of which is drivingly connected to the audio output. As shown, the control means is connected to the bridge network to function in the manner described in connection with other embodiments. The instrument is any instrument capable of generating electrical signals corresponding to musical tones, whereas the bridge network may be a simple single resistance bridge or any of the other bridge arrangements disclosed and may include cascaded bridge networks. The control means are, of course, connected to at least one leg of the bridge network or networks to effect the required phase shift as previously described. The audio output unit includes a loud speaker and may, if necessary, include an amplifier.

I claim:

1. In combination, an instrument for producing electrical signals of frequencies corresponding to musical tones to be reproduced; a bridge network having an input and an output; means connected to the input of said bridge network for applying said electrical signals to said input; an audio output system including a loudspeaker; means coupling the output of said bridge network to said audio output system in driving relationship thereto; and control means connected to at least one leg of said bridge network for cyclically varying, at a controlled rate, the magnitude of phase shift introduced by said bridge network into said electrical signals, said control means being arranged to vary the impedance of at least one arm of said bridge network at said controlled rate.

2. A device as defined in claim 1 in which said bridge network includes two parallel branches across which said electrical signals are applied, the first of said branches comprising a voltage divider with a first intermediate terminal, the second of said branches comprising a resistance and a reactance connected in series at a second intermediate terminal, said intermediate terminals defining said output of said bridge network.

3. A device as defined in claim 1 in which said one arm of said bridge network includes a resistance element, the resistance of which is a function of the voltage applied thereto, said control means including means for applying a cyclically varying control voltage to said resistance element.

4. A device as defined in claim 1 in which said one arm of said bridge network includes: a vacuum tube operated as a variable reactance, said control means including a source of a cyclically varying voltage; and means for coupling said source to said vacuum tube for controlling the reactance thereof.

5. A device as defined in claim 1 in which said one arm of said bridge network includes: a vacuum tube operated as a variable resistance, said control means including a source of a cyclically varying voltage; and means for coupling said source to said vacuum tube for controlling the resistance thereof.

6. A device as defined in claim 1 wherein said bridge network has a first branch with two resistances connected in series at a junction, and a second branch with a resistance and a capacitance connected in series at a junction, said input being coupled across said branches, said output being coupled across said junctions, one of said resistances being a vacuum tube operated as a variable resistance, the magnitude of the resistance of said vacuum tube being a function of a control voltage coupled thereto, said control means comprising an oscillator for generating a cyclically varying control voltage having a frequency less than that of the frequency of the output of said instrument; and means for coupling said control voltage to said vacuum tube.

7. In a vibrato system for an electrical musical instrument for operation with a source producing electrical signals of frequencies corresponding to tones to be reproduced, the combination of: a plurality of bridge networks, each having an input and an output; circuit means connecting said bridge networks in cascade with the output of one bridge network connected to the input of the following bridge network; means connecting the source of signals across the input of the first of said bridge networks; an audio output system including a loud speaker; means connecting the output of the last of said bridge networks to said output system in driving relationship; and control means connected to at least one arm of each of said bridge networks for cyclically varying, at a controlled rate, the magnitude of phase shift introduced by said bridge networks into said electrical signals, said control means being arranged to vary the impedance of said arms of said networks at said controlled rate.

8. A device as defined in claim 7 in which said circuit means includes a pair of conductors directly connecting the output of the preceding bridge network to the input of the following bridge network, and in which the characteristic impedance of said following bridge network is several times the characteristic impedance of said preceding bridge network.

9. A device as defined in claim 7 in which said circuit means includes a transformer with a first winding coupled to the output of the preceding network and a second winding coupled to the input of the following bridge network.

10. A device as defined in claim 7 in which said circuit means includes: a vacuum tube having a cathode, plate and grid, and an input-output reference point, the output circuit load of said vacuum tube being divided between plate and cathode circuits; means coupling the output of the preceding bridge network to said grid and said input-output reference point; and means coupling the input of the following bridge network to said plate and cathode, said input-output reference point being a common reference for the outputs of both of said bridge networks.

11. A vibrato system for use in an electronic musical instrument comprising a signal input, a bridge network having two legs connected to said input, an output system connected to the other end of said bridge network, an electronic cyclical control means connected to one leg of said bridge network, for producing a vibrato effect.

12. In an electrical musical instrument, the combination including two sources of audio tone signals having a substantially 180 degrees out of phase relationship, means including a plurality of impedances serially connected across said signal sources for combining said sources of signals, means for varying at least one of said impedances at a selected vibrato rate independently of said other impedance, and output paths connected to said sources and said serially connected impedances for providing a third audio signal having a constant amplitude and varying in frequency at said vibrato rate with respect to said first and second audio signals.

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