

Oct. 21, 1969

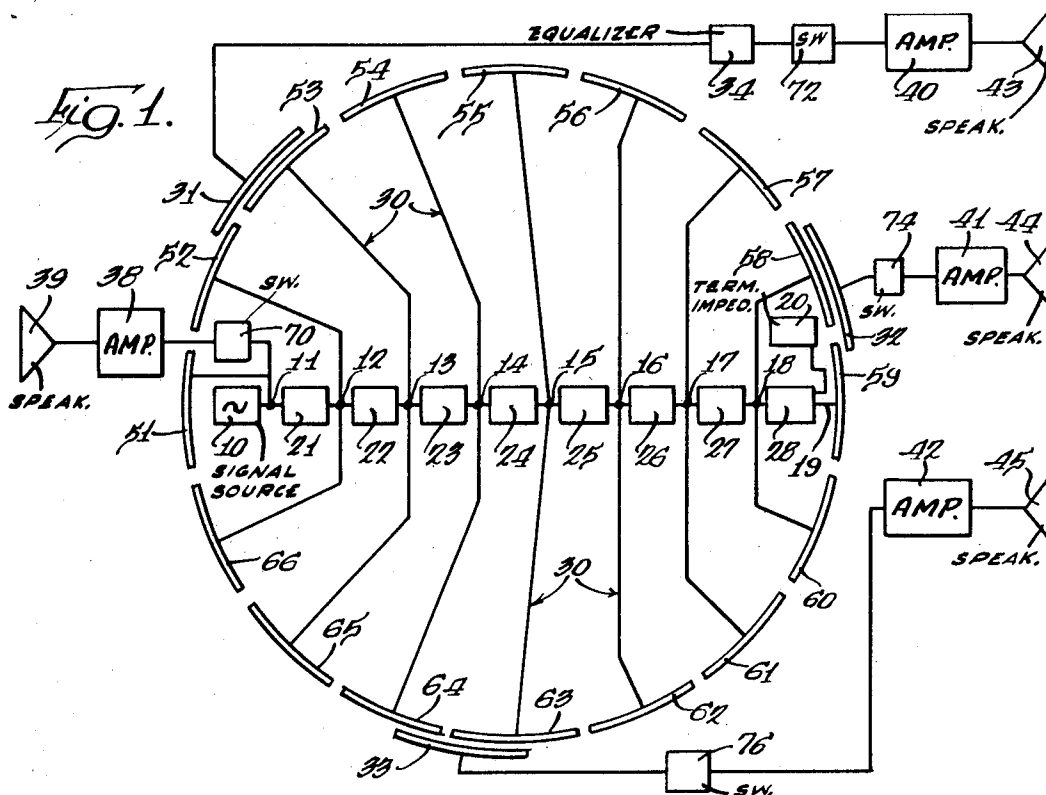
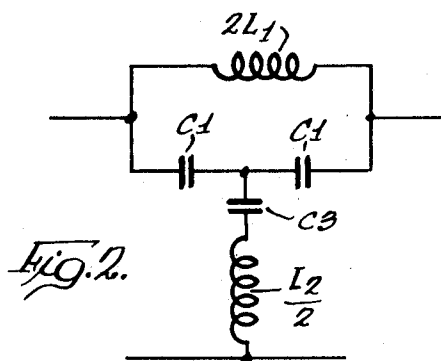
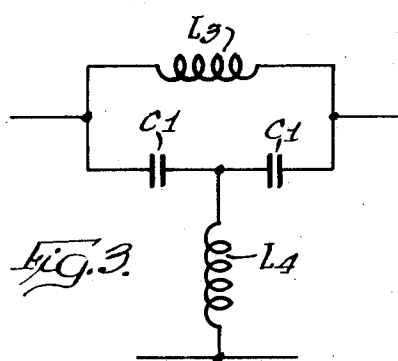
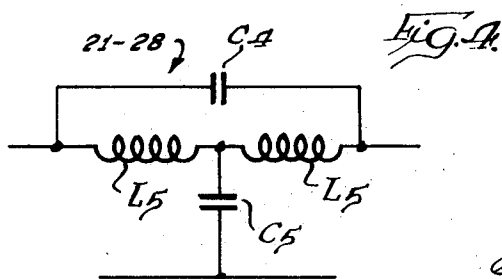
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3,474,181

ELECTRICAL MUSICAL INSTRUMENT ANIMATOR OF THE SCANNED
PROGRESSIVE PHASE SHIFT TYPE

Filed June 2, 1966

3 Sheets-Sheet 1



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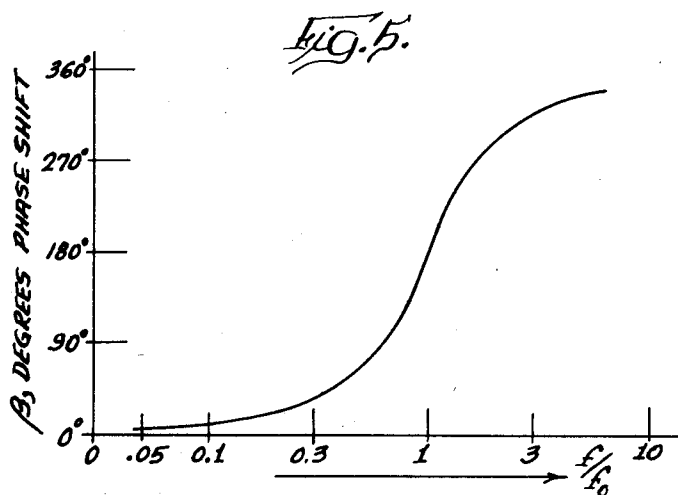
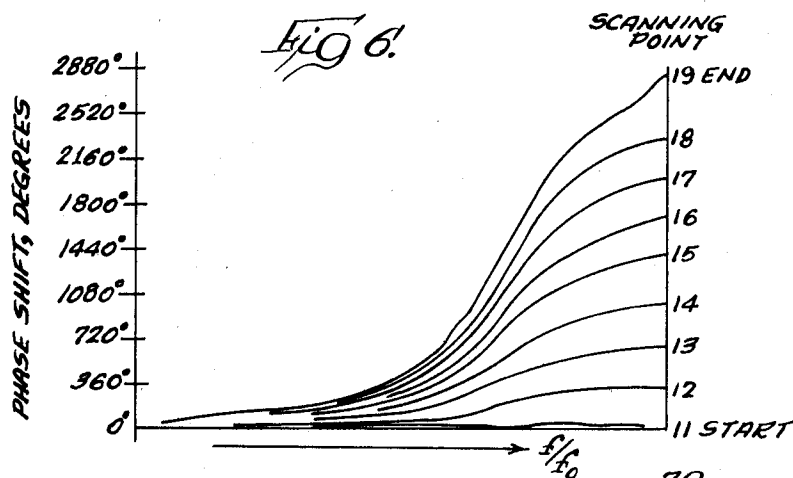
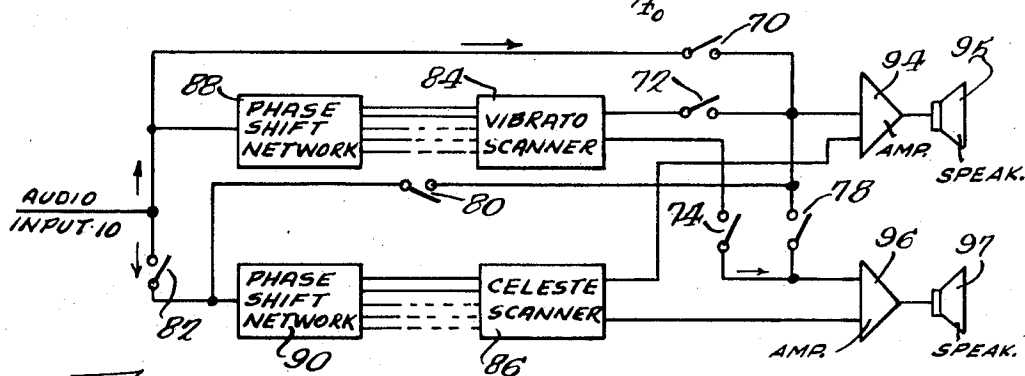
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

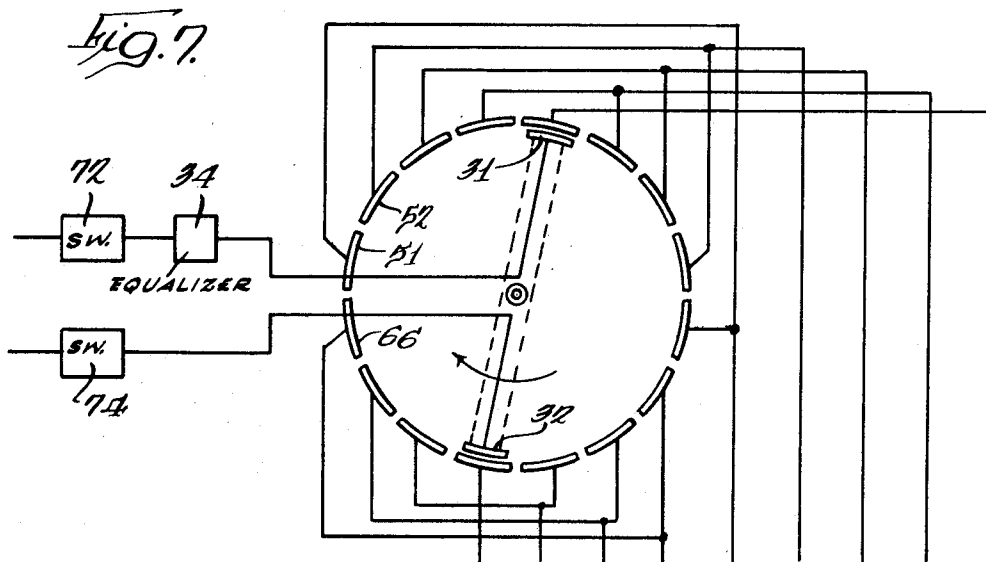
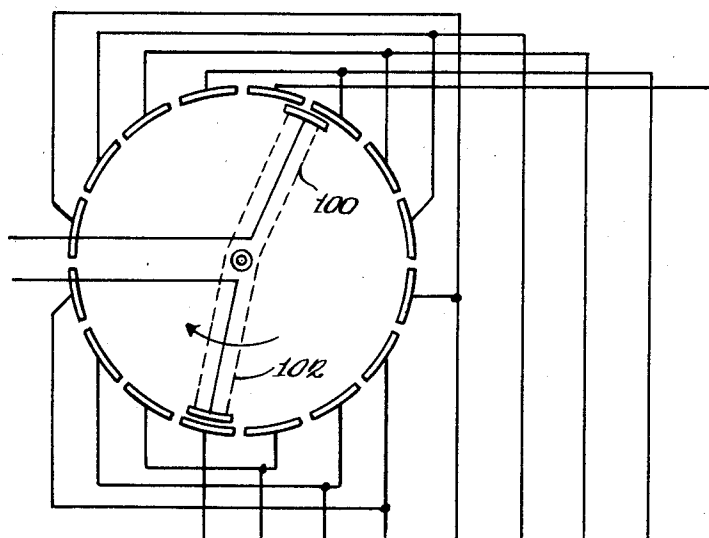


Fig. 9.



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ELECTRICAL MUSICAL INSTRUMENT ANIMATOR OF THE SCANNED PROGRESSIVE PHASE SHIFT TYPE

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U.S. Cl. 84—1.25

4 Claims

ABSTRACT OF THE DISCLOSURE

An electrical musical instrument signal animation system of the scanned phase shift line type in which multiple scanners scan at different speeds or are phase displaced to suppress audible transients. A bridged-T phase shift section having a pair of identical inductances and a pair of capacitors at a four to one ratio is also disclosed.

This invention relates broadly to method and means for improving musical tones, and is more particularly concerned with modified electrical tone signals in electrical musical instruments such as those of the organ type, to produce vibrato, celeste, and chorus animation, whereby an effect pleasing to the ear is achieved.

Vibrato is a continuous cyclical fluctuation of pitch about the nominal pitch frequency which generally increases the emotional quality of music. Celeste as herein described relates to an effect produced by playing a slightly sharp and a slightly flat tone together, whereas two or more tones of very slightly differing pitch combine to produce a chorus effect.

This electrical signal animator is based upon the scanning of successive sections of an all-pass phase-shift network. In its more simple form the phase modulation is accomplished by moving two sensors in opposite directions along the line as shown in the patents to Hanert, Nos. 2,382,413 and 2,905,040 and the copending application of Schrecongost, Ser. No. 482,848, filed Aug. 26, 1965, to produce two output signal frequencies for each component of input frequency. A refinement consists of employing more than two sensors, symmetrically displaced for enhancement particularly in the vibrato and chorus modes of operation. The system is particularly useful in achieving a multiple generator effect, for example, in enriching the sound of an electrical musical instrument.

While in pipe organ practice practical celeste action ordinarily is confined to voices having high constancy of pitch, such limitation does not apply in usage of the animator described here. Any or all voices may be animated at the discretion of the organist. The effect is essentially traditional with solo voices, and full and exciting on richer more harmonically complex organ voices.

As practiced in a preferred form of the invention, the basic combination comprises a pair of capacitive scanners sequentially sampling signal voltages along a multi-section all-pass-phase-shift network. The arrangement provides a musically desirable animation of all tones. As compared with other scanner type animators, the animator here described permits a substantial saving of electrical components. The circuit is applicable directly to organs of either the sine-wave-combining type, or of complex wave form with electrical formant control. The same circuit may be used with either, thereby permitting the added economy of a design common to a variety of instruments.

Prior art circuits used for the above purposes generally have employed artificial delay lines composed of lumped series inductances and lumped shunt capacitances. A notable difficulty encountered with such delay lines has been

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a very large number of filter sections required for the needed delay-bandwidth product. Thus moving the cut-off frequency upward may be done only at the expense of reduced phase-shift or time delay per section.

The present invention avoids these difficulties and extends the bandwidth without limit by the use of passive, all-pass filter sections while increasing the low frequency and mid frequency phase shift or time delay by a substantial factor. Specifically, in an organ application covering frequencies up to 8,000 c.p.s., a satisfactory celeste action by the prior art slow-scan method may be achieved with 48 series inductors and 48 shunt capacitors, scanned with a 32-station scanner. The present invention secures equivalent results with only 16 inductors and 16 capacitors, scanned with a 16-stator scanner for the vibrato and celeste scanners. Furthermore, it is possible with the various means described to achieve unique musical effects which have not been obtainable previously.

One of the objects of this invention is to produce vibrato animation in a musical instrument tone signal by passing such a signal through a passive, phase-shift network having progressively phase shifted output terminals along its length composed of a multi-section, all-pass-phase-shift network, scanning the line to produce a signal having a different frequency compared to that of the input signal and bearing about the input frequency.

A further object of this invention is to produce celeste animation in a musical instrument tone signal by passing such a signal through a phase-shift network and simultaneously scanning said network cyclically in a to and from manner to produce two separate signals bearing about the input signal, separately translating into sound the two signals produced by the scanning operation to produce two separate signals having different new frequencies compared to that of the input signal, one being higher and the other lower than that of the input frequency.

A further object of this invention is to produce a chorus effect in an electrical tone signal by passing an input tone signal through a phase-shift network such as an audio-frequency delay line providing uniformly phase shifted signal output terminals along its length at which the amplitudes of the signal traversing the line are substantially the same, scanning the transmission line cyclically in a to and from manner and separately translating into sound the phase-displaced signals, to produce an output which is an acoustical mixture of the phase-displaced signals.

A further object of this invention is to provide a scanner which prevents simultaneous nulls in the listening channels caused by a 180° phase-shift between adjacent scanning stations.

A further object of this invention is to provide a sound animation system capable of strong phase modulations while extending the apparent "once-around" or repetition period by a substantial amount.

A further object of this invention is to provide a sound animation system in which vibrato, celeste, and chorus effects may be used individually or combined to achieve extreme flexibility in sound animation.

A further object of this invention is to provide a sound animator system offering simplicity and economy.

Other objects and advantages will appear from the following description of a preferred embodiment of the invention, reference being made to the accompanying drawings wherein similar characters of reference refer to similar elements in the several figures.

In the drawings:

FIG. 1 is a diagrammatic representation of the system embodying the present invention;

FIG. 2 is a schematic diagram of a typical all-pass network of the prior art;

FIG. 3 is a schematic diagram of a modified all-pass network;

FIG. 4 is a schematic diagram of a simplified phase-shift network of the bridged-T type as used in this invention to achieve phase-shift;

FIG. 5 is an output curve of the phase-shift vs. frequency for the bridged-T network used in this invention;

FIG. 6 is a frequency curve showing the phase-shift outputs along the delay line used in this invention;

FIG. 7 is a diagrammatic representation of a symmetrical two sensor scanner;

FIG. 8 is a block diagram of the animation system of this invention; and

FIG. 9 is a diagrammatic representation of a non-symmetrical two sensor scanner.

In the illustrative embodiments set forth below, the invention is described as applied to an electric organ. The arrangement illustrated in the drawings and described below is used with one or more keyboard sections of an electric organ.

Referring now to FIG. 1 which shows the general arrangement of a system embodying the present invention, the apparatus there shown comprises a source 10 of complex audio frequency signals of the type, for example, usually provided by the output circuit of one or more sections of an electric organ. Source 10 therefore may be any musical signal source, including whatever keying system, formant circuits, reverberation apparatus, percussion system or other effects are desired, and the signal from such source 10 is impressed upon a terminal 11 which is connected to a passive, multi-section, all-pass phase-shift network composed of individual bridged-T networks 21 through 28 and having an adjustable terminating impedance 20. A convenient number of sections for the purpose described is eight, requiring sixteen stator sections on the scanner. The input and output of each of the individual bridged-T networks are terminals 11 through 19 which are connected to capacitive stator elements 51 through 66 by leads 30. Capacitive rotor sections 31 to 33 move close to the stator elements and pick up the phase shifted signals and then supply them to an output system composed of amplifiers 40 to 42 and speakers 43 to 45, respectively, where the signals picked up by the rotating elements 31 to 33 are translated into sound. In addition, amplifier 38 and speaker 39 are supplied directly from source 10. Switches 70, 72, 74 and 76 designate the channel selection system by which the output sound is controlled. One or more attenuation networks such as 34 in the circuit from pickup 31 may be included to facilitate the equalizing of sound outputs from the two or more listening channels.

FIG. 2 is a showing of a conventional all-pass network having equal capacitances in the arms C_1 and unequal inductances L_1 and L_2 where:

$$f_0 = 180^\circ \text{ phase shift point}$$

$$a = \frac{1}{f_0}$$

$$b = \frac{1}{f_0^2}$$

$$L^1 = \frac{aR}{2\pi}$$

$$C_1 = \frac{b}{2\pi aR}$$

$$L_2 = R^2 C_1$$

$$C_2 = \frac{L_1}{R^2}$$

$$C_3 = \frac{2C_1 C_2 R}{C_1 - C_2}$$

FIG. 3 is a showing of a simplified bridged-T network

in which $a=1$. The capacitances C_1 are equal, but the inductance ratio is $L_2/L_1=4$ where:

$$C_1 = \frac{1}{2\pi f_0 R}$$

$$L_3 = \frac{R}{\pi f_0}$$

$$L_4 = \frac{R}{4\pi f_0}$$

The lattice networks from which the circuits in FIGS. 2 and 3 are derived offer great flexibility of design and performance, but are quite costly as they require push-pull excitation and push-pull readout. The lattice network has a bridged-T counterpart throughout a wide range of circuit parameters. A special case which accomplishes the desired effect in a design employing like coils throughout is shown in FIG. 4.

FIG. 4 is a bridged-T network as used in delay line sections 21 through 28 shown in FIG. 1, in each section of which there are equal inductances

$$L_3 = \frac{R}{2\pi f_0}$$

in the arms and unequal capacitances

$$C_4 = \frac{1}{4\pi f_0 R}$$

and

$$C_5 = \frac{1}{\pi f_0 R}$$

ratio of $C_5/C_4=4$.

FIG. 5 is a response curve of the bridged-T network shown in FIG. 4. It is a phase shift versus frequency curve which is normalized about frequency f_0 for an all-pass bridged-T network which has equal inductances.

While the required capacitances in the circuit of FIG. 3 are of equal value, the required inductance values are different. The required inductors do not occur in repeated series connection. However, this manufacturing disadvantage is avoided by intentional change of signs of the reactances. Thus, each reactance in FIG. 4 is given a value of opposite sign and equal numerical value at the inflection point frequency. This reversal allows the use of equal coils in the basic configuration and provides a substantial advantage since the coils represent the principal cost of the phase-shift network.

Phase shift and amplitude response tests show that the performance of the inverted network of FIG. 4 is identical with its equal-capacitance counterpart.

The phase shift at f_0 is 180° as shown in FIG. 5, where in the curve is normalized about frequency f_0 . The corresponding amplitude response is perfectly flat with a single section having optimum circuit values and lossless reactors. In practice, this response for a single section exhibit a dip at f_0 of roughly 0.5 db when coil Q equals 50. When sections are cascaded, phase-shifts add, and likewise the amplitude response dip becomes more pronounced.

In FIG. 6 is shown the measured phase response versus frequency, normalized about f_0 , of the phase-shift network comprising eight sections 21-28 of the all-pass filter.

The overall response is of interest only when the scanning sensor looks at the end 19 of the phase-shift network. At other sectional joining points 11 to 18, intermediate degrees of phase-shifts are encountered, values of which are shown in FIG. 6 and may be utilized by scanning along the network. This sequence yields a progressively increased phase shift followed by a progressive decrease in phase shift on the return trip of the scanner. Thus the signal at the scanning sensor is phase modulated in a linear manner, thereby yielding a substantially constant fractional frequency shift during either direction of sensor motion along the scanned line. A representative

rate for celeste scan is $\frac{1}{10}$ to 1 complete repetition per second.

In particular, as the scanner moves in a direction such as to encounter increasing phase shift, fewer signal cycles are intercepted per second, with the result that the apparent frequency is lowered during such transition. Similarly, as the scanner moves in the opposite direction, decreasing phase shift is encountered. Added signal cycles are encountered per second, and the apparent frequency is raised during such transition.

If the scanner were merely switched abruptly from one network junction to the next, frequency variation as such would not be noted, but rather an abrupt discontinuity in signal phase. To produce the desired effect the scanner transition must be accomplished smoothly so that the scanner pickup voltage always is a vectorial addition of signal voltages at the two junction points between which the scanner happens to be. Such smooth transition may be accomplished very readily with a capacitive type scanner as employed in the scanner vibrato system, as described in Hanert U.S. Patent No. 2,382,413. In such a scanner, the shapes of the rotor plates closely match the stator plates, and adjacent stator assemblies are separated only slightly from each other.

As is well known, a conventional scanner type animator enters a different mode of operation when the phase shift between network junction points is at or near 180° . In that circumstance, equal and opposite voltages are presented to a scanning sensor, with the result that no output whatever occurs. The resulting momentary null or cessation of output signal can cause an annoying audible effect.

In order for full economy to be achieved by usage of sections of this type, it is required that the 180° phase shift point per section lies in midband. At that frequency, equal-amplitude voltages of opposing phase are sensed when a sensor is at its transitional position exactly midway between adjacent stator sections resulting in an output null occurring at that instant. Several methods are available by which such cancellation effects may be lessened, if desired.

With three or more sensors, equally spaced on the rotor as in FIG. 1, a number of equally spaced scanning stations or stator elements may be selected such that only one scanning sensor senses a null at any particular instant. At least one listening channel will always be active. For example, with the three equally spaced sensors 31, 32, 33 scanning 16 equally spaced stations 51-66 shown in FIG. 1, the sensors are $\frac{5}{3}$ stator stations apart. Thus when one sensor is in null position, the other two rotors are separated from null position by an arc equivalent to one-third of a stator width.

With four equally spaced sensors scanning 18 equally spaced stations, diametrically opposed pairs of sensors pass null points at like instants. But since the equivalent spacing between sensors is $4\frac{1}{2}$ stations, adjacent sensors cannot be in null positions at the same instant.

FIG. 7 shows the generally preferred configuration of two sensors diametrically opposed and an even number of stator stations; the sensors encounter null situations simultaneously. With 16 stator stations, 16 such nulls are encountered per complete revolution of the rotor shaft. With a shaft speed of $\frac{2}{3}$ r.p.s. as is representative in the practice of this invention for celeste purposes, the nulls are repeated $(\frac{2}{3})(16) = 10\frac{2}{3}$ times per second. The phenomenon may be heard as a rapid and pronounced tremulant over a frequency span of about an octave centered at the critical frequency f_0 .

The elapsed time from an output peak, occasioned by a rotor being centered at stator position, to an output null, occasioned by a rotor lying midway between stator elements is, in the case cited, $\frac{1}{2}$ of a full rotation, or an elapsed time of $(\frac{2}{3})(\frac{1}{2}) = \frac{1}{3}$ second. It is found, however, that the influence of reverberation, natural or artificial, produces enough sound during sensor nulls to pre-

vent the complete cessation of sound. As a practical matter, the cited arrangement may be used in conjunction with an f_0 as low as about 2,000 c.p.s. and impart a highly pleasing animation to the sound.

A contributing influence to success of the simple system is that in generalized organ registration and playing, numerous frequencies are involved simultaneously, only a narrow band of which is subject to the special phenomenon just described. Thus the overall effect is quite acceptable, particularly if vibrato or other tremulants are present, except possibly in special situations such as mellow voices played at 2-foot pitch.

The operation will now be described with respect to FIGS. 1 and 7. The network may be scanned with one or more scanning sensors 31 to 33 which, for celeste purposes, preferably are uniformly spaced in time in their scanning motions. As shown in FIG. 1, three sensors may be used each with its recovery amplifier 40 to 42 and sound output channel 43 to 45, respectively. More than three sensors yield diminishing returns for the equipment required. The number of scanners used influences the smoothness and fullness of transition, but for most purposes two diametrically opposite scanners as in FIG. 7, and two corresponding listening channels as shown in FIG. 7, give the essential effect, and unless otherwise noted, the following description of operation assumes use of two channels.

FIG. 1 indicates acoustical mixing of the phase differing signals. Electrical mixing of phase differing signals, because of direct cancellation and reinforcement, gives an audible effect that is not as pleasing as acoustical mixing, except at frequencies lower than several hundred cycles per second, wherein it makes no appreciable difference. Thus in a listening channel for low tones—for example, up to 400 cycles—electrical mixing may be used satisfactorily, thereby avoiding need for separate bass outputs. This degree of freedom is particularly useful in view of the fact that channel division is most costly in the deep bass region where large speakers and enclosures and high power requirements introduce considerable expense.

In organization of the complete instrument, this electrical signal animator is applied as shown in FIG. 8 utilizing a separate vibrato 84 and celeste scanner 86 supplied from phase-shift networks 88 and 90. The vibrato scanner 84 is run at 5 to 8 revolutions per second to produce vibrato animation. To achieve smoothest performance in vibrato operation, it is preferred to vary the accrued phase shift for each scanning station to approximate a sinusoidal variation of phase modulation with time. For those line portions in which greater phase shift is appropriate, two or more delay sections may be inserted. Particularly if the intensity or degree of vibrato is not varied, larger phase shifts when appropriate are achieved merely by employing different circuit component values in the various delay sections.

In an entertainment type instrument, the overall animation can be made most pronounced by compounding a celeste effect with mixed or separate vibrato treated signals, and non-vibrato signals, in a variety of ways. A particularly effective arrangement is that as shown in FIG. 8 in which the vibrato animation may be applied to the input channel of the celeste scanner 86 through switch 80.

Closing of selected switches 70, 72, 74, 78, 80 and 82 determines the animation which is to be supplied to amplifiers 94, 96 and speakers 95, 97.

Dual vibrato, as used herein, refers to opposed phase modulations achieved by rotating the scanner 84 between 5 to 8 r.p.s. and applied to the separate output speaking channels, speakers 95 and 97, whereas simple vibrato is limited to one phase of vibrato applied to both output channels via closure of switches 72 and 78.

Vibrato chorus, as used herein, refers to a mixture of vibrato from one speaker 97, switch 74, and non-vibrato from a second speaker 95, switch 70.

Celeste refers to slow-scan, preferably about $\frac{3}{8}$ revolutions per second, phase modulation of scanner 86 of opposed sense being applied to separate listening channels, speakers 95 and 97, via switch 82.

Through the use of finger tabs (not shown), the organist may use various combinations of these switches 70, 72, 74, 78, 80 and 82 to modify the nature of the animation. Maximum complexity of animation is achieved when switches 70, 72 and 80 are closed (other switches in FIG. 8 being open). For added animation, the driving impedance and/or terminating impedance 20 of the all-pass, phase-shift network composed of sections 21 to 28 is upset as is well known. In general, such upset is not appropriate when celeste is used alone, but it may be helpful when celeste is combined with other animation.

For improved rendition of organ music of a classical or liturgical nature, wherein voices often are played slowly and without tremulant, a substantial smoothing of the celeste action can be highly desirable. A simple way to effect considerable improvement is to displace one sensor element 102 slightly, so that the two sensors 100, 102 are not exactly diametrically opposite, as shown in FIG. 9. The optimum displacement is one-half the angular indexing of successive stator stations. For example, with two sensors sensing 16 equally spaced stators, one sensor is displaced by $(\frac{1}{32})(360^\circ) = 11\frac{1}{4}^\circ$ from being diametrically opposite. Thereby when one sensor senses a null, the other is sensing maximum signal, with the result that the imparted audible tremulant is made small.

Alternatively, non-uniform spacing of the stator elements is possible if avoidance of simultaneous nulls is a prime consideration. Actually, such non-uniform spacing imparts a pronounced additional element of once-around or periodicity to the animated sound and therefore ordinarily is a less desirable method.

Another means of avoiding simultaneous nulls in the two sensor outputs is that of forming the delay line of all-pass phase-shift sections having different values of f_0 . For example, values may be chosen of 1,500 and 2,700 c.p.s. for alternate sections or groups of sections. By this means, for any one input frequency, no more than one sensor (of a diametrically opposite pair) can encounter deep null at any instant. For optimum network performance of this configuration, the same operating impedance is maintained even though two or more values of f_0 are used.

An important aspect of authenticity of either a chorus or celeste effect is the degree to which an apparent and unrelenting periodicity has been avoided, combined of course with the production of phase interference patterns which vary according to the note combination being played. The slower the playing tempo, the more apparent is a once-around or other periodicity. An obvious possibility is merely to slow the rate of scan, particularly for a modest chorusing action. But the sacrifice of celeste action is proportionate to the scanning speed, and hence is not an optimum solution for the latter purpose. For those applications which warrant it, the effective repetition period is extended to many seconds without loss of scanning speed itself.

An alternative system to avoid "once-around effect" can use two dual rotor scanners running at slightly different speeds. By making the shaft speed of each dual rotor differ from each other only very slightly, the net once-around period is multiplied as desired.

The double dual approach may be used with any combination of the above described additional methods. Also, any combination of these methods may be used in the production of vibrato modulations, whether in conjunction with all-pass phase-shift network configurations, or with any other form of scanned delay network.

In summary, it is seen that a prime aspect of this invention is the employment of an optimized, passive, all-pass phase-shift network. Although a capacitive scanner pickup has been shown, it will be understood that for

the sensing function itself there are substantial equivalents such as variable resistances, or inductances, the use of light-dependent resistors, etc., all within the basic spirit of applying a scanned all-pass phase-shift network to the problem of securing animation.

From the accompanying drawings and the foregoing description of illustrative embodiments of my invention, those skilled in the art will be able readily and without the exercise of invention to design, construct, and operate a device in accordance with the invention for producing vibrato, celeste, chorus, or a combination of these animation effects in sounds originating in the form of electrical signals.

I therefore desire by the following claims to include within the scope of my invention all such similar modified forms of the apparatus and method disclosed by which substantially the results of my invention may be obtained by substantially the same or equivalent means.

I claim:

1. An apparatus for improving sound animation derived from a source in which the sound is in the form of an electrical signal, including a passive, all-pass phase-shift network having a plurality of terminals along its length adapted to provide progressively phase shifted signal terminals and coupled to said source to receive signals therefrom, a plurality of stationary scanner segments respectively coupled to said terminals in a manner such that cyclic movement of a scanner pickup means adjacent said stationary segments will scan said phase-shift network in an effective to and fro manner, a plurality of said scanner pickup means cyclically movable relative to said stationary segments, means for moving said pickup means at different speeds relative to said stationary segments, and output means for translating into sound the signals appearing on each of said pickup means.

2. An apparatus for improving sound animation derived from a source in which the sound is in the form of an electrical signal, including a passive, all-pass phase-shift network having a plurality of terminals along its length adapted to provide progressively phase shifted signal terminals and coupled to said source to receive signals therefrom, a plurality of stationary scanner segments respectively coupled to said terminals in a manner such that cyclic movement of a scanner pickup means adjacent said stationary segments will scan said phase-shift network in an effective to and fro manner, a pair of said scanner pickup means movable relative to said stationary segments, said pickup means being displaced from geometric symmetry by an indexing amount substantially equivalent to the spacing between positions for maximum and minimum output from said scanning pickup means, and output means for translating into sound the signals appearing on each of said pickup means.

3. An apparatus for improving sound animation derived from a source in which the sound is in the form of an electrical signal, including a passive, all-pass, phase-shift line having a plurality of phase shift sections and terminals along its length adapted to provide progressively phase shifted signal terminals and coupled to said source to receive signals therefrom, said phase shift sections comprising a pair of identical inductances in series and in series with others of the phase shift sections in the phase shift line, a capacitor bridging both said inductances, a second capacitor connected between said inductances and a second line common to all said phase shift sections, the second said capacitor having a value substantially four times the value of the first said capacitor, means for scanning said terminals in a manner such that cyclic movement of the scanning means will scan said phase-shift network in an effective to and fro manner, means for cyclically moving said scanning means, and output means for translating into sound the signals appearing on said scanning means.

4. An apparatus for improving sound animation derived from a source in which the sound is in the form of

an electrical signal, including a passive, all-pass phase-shift network having a plurality of terminals along its length adapted to provide progressively phase shifted signal terminals and coupled to said source to receive signals therefrom, a plurality of stationary scanner segments respectively coupled to said terminals in a manner such that cyclic movement of a scanner pickup means adjacent said stationary segments will scan said phase-shift network in an effective to and fro manner, a plurality of said scanner pickup means cyclically movable relative to said stationary segments, the number of said terminals not being whole number divisible by the number of pickup means, and output means for translating into sound the signals appearing on each of said pickup means.

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References Cited

UNITED STATES PATENTS

2,899,644	8/1959	Leslie	84—1.26	X
2,905,040	9/1959	Hanert	84—1.26	
3,122,716	2/1964	Whang	333—76	X
3,258,519	6/1966	Young	84—1.24	X

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U.S. Cl. X.R.

84—1.24; 331—106; 333—76