Dec. 8, 1964 D. L. BONHAM 3,160,695

ELECTRICAL MUSIC SYSTEM

Original Filed March 2, 1959 2 Sheets-Sheet 1

FIG. 1.

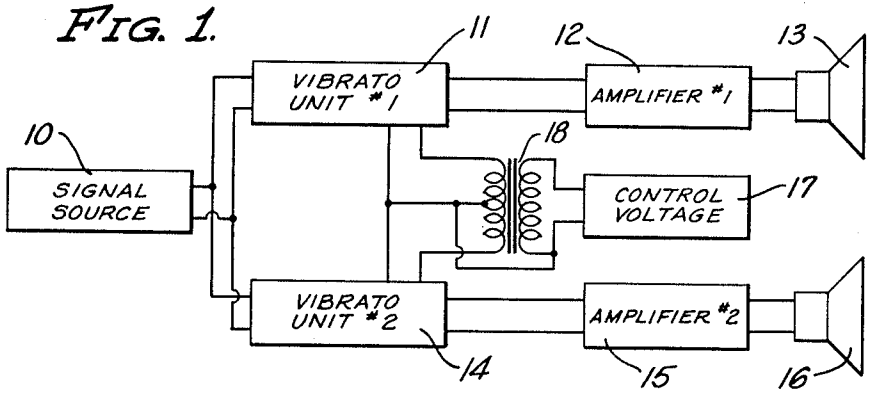


FIG. 2.

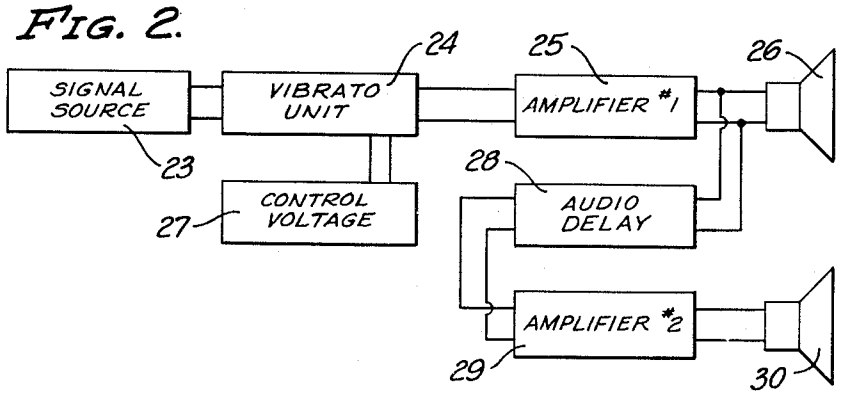
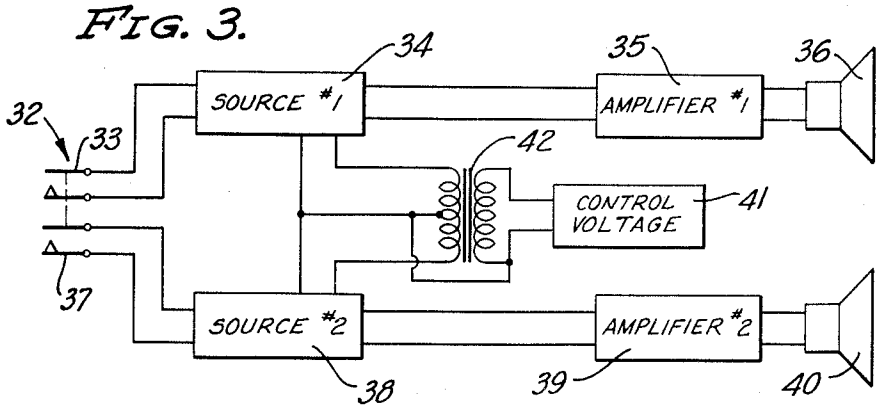


FIG. 3.



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ELECTRICAL MUSIC SYSTEM

Original Filed March 2, 1959 2 Sheets-Sheet 2

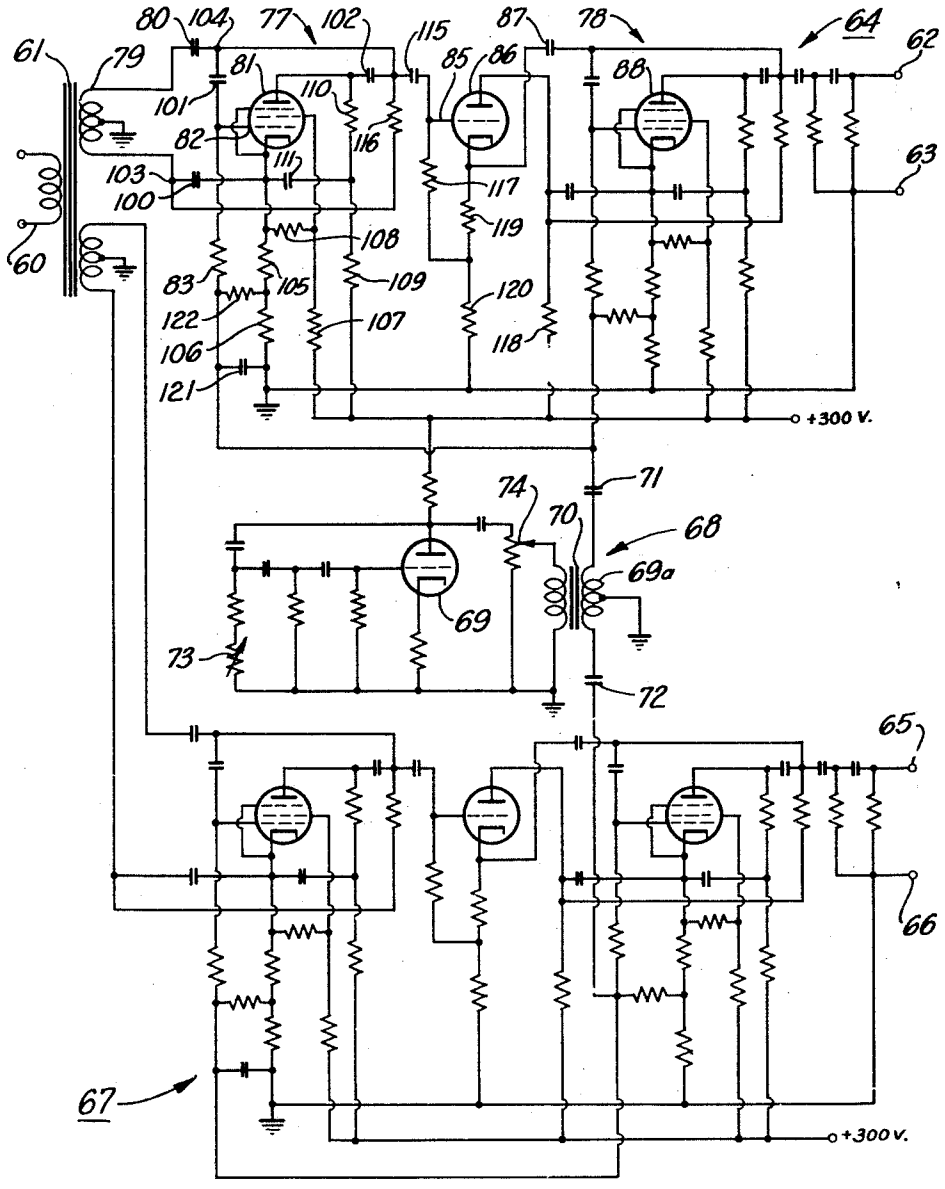

FIG. 4.

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3,160,695

ELECTRICAL MUSIC SYSTEM

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Original application Mar. 2, 1959, Ser. No. 796,424, now Patent No. 3,083,606, dated Apr. 2, 1963. Divided and this application Dec. 10, 1962, Ser. No. 258,091
2 Claims. (Cl. 84—1.25)

This invention relates to electrical music systems suitable for use with electric music instruments such as organs, guitars and accordions, as well as with tape, record and microphone inputs. In particular, the invention relates to apparatus for improving the tone quality of electrical music systems.

It is an object of the invention to improve the vibrato effect used widely in music by reducing the effect of wandering pitch on reiterated tones. A further object is to provide apparatus for adding richness and depth to vibrato without altering the traditional nature and usefulness of the vibrato effect. Another primary object of the invention is to add to musical tones, especially those of the organ type, certain characteristics associated with unusually large instruments and acoustical environments, this effect often being referred to as "ensemble."

It is an object of the invention to provide an electrical music system utilizing two or more audio channels with means for introducing phase shift cyclically varying at a relatively low rate into at least one of the channels. A further object of the invention is to provide such a system wherein the cyclically varying phase shift is introduced into each of the channels out of phase. Another object is to provide such a system where the phase difference is in the order of 180 electrical degrees for the two channel system and in the order of 360 electrical degrees divided by n for an n channel system.

It is an object of the invention to provide such a music system which can utilize various types of vibrato and phase shift components including those circuits disclosed in my copending application, "Electrical Vibrato and Tremolo Devices," Serial No. 414,589, filed March 8, 1954.

The present case is a divisional application of my application for "Electrical Music System," Serial No. 796,424, filed March 2, 1959, now U.S. Patent No. 3,083,606 which is a continuation-in-part of said No. 414,589.

Vibrato may be defined as a cyclical raising and lowering of pitch at a rate which is low relative to the audio band of the signal being handled, ordinarily in the order of four to seven cycles per second. It is produced in many ways, such as by moving the finger back and forth along the string of a violin, oscillating the slide of a trombone, varying the wind pressure in a pipe organ, varying parameters in the oscillators of an electronic organ, and by the circuitry described in my aforesaid copending application. Vibrato is an essential of most forms of music. However, adding vibrato to some instruments such as the electronic organ results in a serious annoyance that may be described as wandering pitch. That is, when the tone is sounded briefly, it may be heard only while the vibrato means is producing raised or lowered pitch, or, in the case of reiterated tones, the pitch may be heard at successively differing pitches, wandering as much as a quarter tone from nominal pitch. Vibrato intensity sufficient to give the most effective results on sustained music will cause reiterated notes in fast moving passages to sound objectionably out of tune, or even comical.

In searching for a remedy for this problem, it has been found possible to retain all the desirable effects of vibrato while virtually eliminating the wandering pitch difficulty. This may be achieved by adding to the normal vibrato-

containing sound channel a second sound channel in which the musical tones have vibrato added to them in a different vibrato phase, ordinarily in the opposite phase. In other words, the second channel raises pitch while the first lowers it, and lowers pitch while the first raises it. A preferred arrangement is one in which the two sound channels are fed through loud speakers separated by two or more feet and so disposed that the sound from each is heard in equal volume, but by somewhat different acoustic paths. The musical result of hearing simultaneously the lowered and raised pitches is actually an enhanced vibrato, but, since the average pitch always remains unchanged as a consequence of the reciprocal action of the two channels, the effect of wandering is eliminated. The enhancement is the product of the rich and complex side bands produced by the combining of different and continuously changing pitches. Accordingly, it is an object of the invention to provide such a combination of components. Furthermore, it is an object of the invention to provide such a combination which may have more than two sound channels, although it has been found by experimentation that the use of three or more channels produces very little improvement in tone quality over a two channel system. Another object is to provide such a system which can utilize a single loudspeaker with a plurality of sound channels, although, of course, individual speakers are preferred from a quality viewpoint.

The invention also comprises novel details of construction and novel combinations and arrangements of parts, which will more fully appear in the course of the following description. The drawings merely show and the description merely describes preferred embodiments of the present invention which are given by way of illustration or example.

In the drawings:

FIG. 1 is a diagram of a preferred embodiment of the invention;

FIG. 2 is a diagram of an alternative embodiment utilizing an audio delay;

FIG. 3 is a diagram of another alternative form having two independent sound sources; and

FIG. 4 is a schematic diagram showing a preferred form of the vibrato units.

In the electrical music system of FIG. 1, each of two audio channels is provided with a vibrato unit, with the two vibrato units being operated in opposite vibrato phase. The output from a signal source **10** is connected to a first audio channel having a vibrato unit **11**, an amplifier **12** and a speaker **13**, and to a second audio channel having a vibrato unit **14**, an amplifier **15** and a speaker **16**. A vibrato unit is a device which introduces phase shift into the signal transmitted by the associated audio channel with the magnitude of the phase shift varying cyclically at a rate which is low relative to the pass band of the channel. The vibrato rate is ordinarily in the range of one-half to ten cycles per second with the range of six to seven cycles per second being preferred while the pass band of an audio channel seldom exceeds a range of thirty to twenty thousand cycles per second. Each of the vibrato units **11**, **14** introduces phase shift into the signal transmitted from the source to the corresponding amplifier in response to an A.C. control voltage which is generated in a control voltage source **17** and coupled to each vibrato unit through a transformer **18**. The secondary winding of the transformer **18** is center tapped with a half winding coupled to each of the vibrato units respectively to provide control voltages which are 180 degrees out of phase with each other. Alternatively a vacuum tube phase splitter may be used in place of the transformer. While various types of vibrato units can be used in the system

of FIG. 1, a preferred form is shown in detail in FIG. 4 and will be described hereinbelow.

The preferred phase difference in the outputs of the two vibrato units in a dual channel system is in the order of 180 degrees. However, this should not be considered a limitation on the present invention and phase differences in the range of 90 to 270 degrees have been used. Where the phase difference is less than 90 or more than 270 degrees, very little improvement in tone quality is achieved.

In the preferred system of FIG. 1, a separate speaker is used for each audio channel and the speakers are preferably located at least two feed apart. The use of speakers for each channel avoids the mechanical sound which results from hearing all components of the sound from both channels at identical levels but different pitch. Also, a stereophonic effect is obtained that adds a sense of spaciousness and third dimension as well as a dispersion of sound that is desirable in virtually every type of music. Of course, the desired side bands are generated by the vibrato units and would be present with a single speaker coupled to both channels, but experiment has shown that the savings in cost is seldom justified in view of the deterioration in results.

The electrical musical system of the invention may be operated with more than two audio channels with the phases of pitch changes introduced by the various vibrato units differing from each other by 360 degrees divided by the number of channels being used. For example, with a three channel system the phase difference would preferably be in the order of 120 degrees rather than 180 degrees. However, it has been found by experiment that the use of more than two channels does not materially improve the tone quality of the system and the three or more channel systems are not used in practice.

In a simplified system, one of the vibrato units could be omitted so that the pitch of one audio channel remains constant while the pitch of the other goes above and below this constant value. When used for vibrato effects at six or seven cycles per second, this simplified system is not especially desirable. However, it is of more value in the ensemble application to be described below.

A different system for producing the desired cyclical variations in pitch in two audio channels out of phase is shown in FIG. 2. Therein the output from a signal source **23** is connected through a vibrato unit **24** to an amplifier **25** and then to a speaker **26**. This channel may be identical to the channel comprising the units **10**, **11**, **12** and **13** of FIG. 1, wth a control voltage unit **27** supplying the control voltage for the vibrato unit **24**. The signal in the first audio channel is also passed through an audio delay unit **28** to an amplifier **29** and a speaker **30**, this circuit comprising a second audio channel. The delay unit **28** introduces a delay into the signal of the second audio channel which is equal to approximately one half the vibrato period. For example, if the vibrato rate of the unit **24** is six cycles per second, its period is one-sixth of a second and the delay in the unit **28** should be in the order of one-twelfth second. Thus, at the moment the output of the first channel goes through its period of raised pitch, the output of the second channel goes through lowered pitch producing the desired out-of-phase pitch variations in the two channels. Of course, the system of FIG. 2 could be used with three or more audio channels with each audio delay unit introducing a different amount of delay, preferably in the same ranges as discussed in conjunction with the system of FIG. 1.

The particular type of audio delay unit used in the system of FIG. 2 is not a feature of the invention. An inductance-capacitance transmission line of conventional design can be used. Alternatively, a length of tubing with a speaker at the input end and a microphone at the output end or a coil spring with a driver at one end and a pickup at the other would be suitable. The delay unit should have a minimum of reflection so that there will be substantially no reverberation. Also the delay should be as constant as possible through the frequency range over which it is operated. Tests have indicated that a delay unit should desirably be operable in the range of 300 to 3000 cycles per second, where vibrato effects are most pronounced.

Optimum vibrato effect is obtained where the delay is equal to one-half the period of the vibrato rate, which corresponds to having the pitch variations exactly 180 degrees out of phase. Of course, this exact figure is not required in the practice of the invention but is preferred. Some systems utilize a variable vibrato and, while it is not necessary that the delay also be variable, it can be synchronized with the vibrato to always produce the optimum delay.

The embodiment of FIG. 3 is suitable for use with electronic organs and similar instruments where more than one tone generator system is actuated by a single key. A key **32** has a first set of contacts **33** which on closing energize a first signal source **34**, the output of this signal source being coupled to an amplifier **35** and a speaker **36**. Another set of contacts **37** is actuated by the key **32** to energize a source **38** with the output of the source being coupled to an amplifier **39** and a speaker **40**. A control voltage for the vibrato of each of the sources **34**, **38** is generated in a control voltage unit **41** and coupled to the two sources out of phase through a transformer **42** in the same manner as in the system of FIG. 1. Each of the sources may constitute an oscillator or other type of tone generator with a separate vibrato unit or the vibrato may be produced directly by varying at vibrato-rate some parameter of the oscillator circuits, such as the grid or plate voltage.

Where the cyclical pitch variation is at a rate in the order of six or seven cycles per second, the effect is referred to as vibrato. However, these same systems may be used in the production of what is termed ensemble. Ensemble may be described as a sounding together, as of many voices or instruments. It is the complex result of the playing together of many violins in an orchestra or many pipes in an organ or the like, no two of which ever sound the identical pitch and phase simultaneously for more than an instant. The ensemble effect is not necessarily associated with vibrato and, in fact, in large choral groups and symphony orchestras, even though the individual voices or instruments may be producing vibrato, the vibratos are averaged out and the tonal effect is one of great warmth and beauty with little or no vibrato audible.

Vibrato is ordinarily characterized by definite periodicity, usually in the order of six or seven cycles per second while ensemble is not. In the ensemble effects described in the preceding paragraph, the beat-rates resulting from the combining of different pitches vary continually and through different amounts for every frequency of tone. However, the ensemble effect can be produced by the electrical music system of the present invention by operating the vibrato units out of phase and at a rate in the order of one-half to one cycle per second. While these very low frequency pitch changes are audible, they have no aural identification as vibrato but do have the effect of the rolling of sound in a large auditorium, a particularly valuable effect in organ installations.

FIG. 4 is a circuit diagram of a preferred form for the vibrato units of the electrical music system of the invention. This circuit may be used in the system of FIG. 1 by coupling the source **10** to a primary winding **60** of an input transformer **61**, the input of the amplifier **12** to the output terminals **62**, **63** of a vibrato unit **64** and the input of the amplifier **15** to the output terminals **65**, **66** of a vibrato unit **67**. The vibrato units **64**, **67** are identical and the former will be described in detail. The control voltage for each of the vibrato units is supplied from a control voltage unit **68** which may comprise a triode

vacuum tube 69 operated as a conventional phase shift oscillator. 180 degree out-of-phase control voltages are fed to the vibrato unit 64 and 67 from a secondary winding 69*a* of output transformer 70 through coupling capacitors 71, 72, respectively. The vibrato rate is controlled by a variable resistor 73 which controls the oscillator frequency, and the vibrato intensity or magnitude is controlled by a potentiometer 74 which varies the amplitude of the control voltage. The vibrato unit 64 comprises two phase shift bridges 77, 78 operated in cascade. Of course, only a single phase shift bridge is required and other types of phase shift circuits, such as those disclosed in my aforesaid copending application, may be used if desired. Secondary winding 79 of the transformer 61 comprises two arms of the bridge, the center tap of the winding being connected to circuit ground. A capacitor 80 serves as the third arm of the bridge 77 and a remote-cutoff pentode vacuum tube 81 constitutes the fourth arm, the tube operating as a variable resistor under the control of the control voltage coupled to its control grid 82 through a resistor 83.

The output from the first bridge 77 is coupled to a grid 85 of a triode tube 86 which, together with its plate and cathode resistors, serves as two arms of the bridge 78. A capacitor 87 and a pentode tube 88 serve as the other two arms of the bridge 78 in the same manner as the capacitor 80 and the tube 81 of the bridge 77. The output from the second bridge 78 is coupled to the output terminals 62, 63 through an RC high-pass filter which substantially removes signals of the frequency of the control voltage from the output.

Referring to the phase shift bridge 77, the cathode of the tube 81 is coupled to the winding 79 through a capacitor 100 and the control grid and plate are coupled to the capacitor 80 through capacitors 101 and 102, respectively, thus completing the bridge consisting of the two sections of the winding 79, the capacitor 80 and the tube circuit. The A.C. voltage from the control circuit 68 and applied to the control grid 82 serves to vary the grid-plate transconductance of the tube and, since the reactances of the coupling capacitors are low compared to the associated resistances, the plate current of the tube is in phase with the grid voltage. Thus, voltages appearing across bridge terminals 103, 104 will produce an in-phase current through the tube and the tube circuit will function as a resistance arm of the bridge, the magnitude of which varies with the vibrato rate control voltage. Direct current ground return for the tube is through a resistor 105, which develops grid bias, and a resistor 106, which is of sufficiently high value to avoid shunting bridge terminal 103 to ground. Screen voltage for the tube 81 is supplied from a voltage divider consisting of resistors 107, 108. Plate voltage is supplied through an isolating resistor 109 and a load resistor 110, with a plate to cathode return provided by a capacitor 111.

The large vibrato rate voltage which appears on the plate of the tube 81 as a result of the control voltage applied to the grid thereof is attenuated before being fed back to the grid circuit and into the output circuit by connecting from the junction of capacitor 102 and a coupling capacitor 115 back to the bridge terminal 103 through a resistor 116, the value of the resistor 116 being low at the control frequency relative to the reactance of the capacitor 102.

The output of the first bridge circuit is coupled to the grid 85 of the tube 86 through the capacitor 115. A grid return resistor 117 is of a value sufficiently low so that, in combination with the reactance of capacitor 115, further attenuation of control frequency voltage is obtained. The tube 82 functions as two arms of the bridge 78 with the signal voltages appearing across plate resistor 118 and cathode resistors 119, 120.

A capacitor 121 is connected between the control voltage output and circuit ground and a resistor 122 is connected between the control voltage output and the junction of resistors 105, 106. The capacitor 121 prevents coupling of the tubes 81 and 88 of the two bridge circuits through their grid returns by bypassing signal frequency to ground. The reactance of the capacitor is sufficiently high at the control frequency to avoid substantial loss of control voltage. The resistor 122 provides a grid to cathode bias return for the tubes 81 and 88.

In the operation of the phase shift bridge, the signal from the source coupled to the primary winding 60 develops two signal voltages which are substantially 180 degrees out of phase in the center tapped secondary winding 79. These signal voltages are applied across the serially connected tube circuit and the capacitor 80, with the bridge output being developed at the junction of the tube circuit and said capacitor. The magnitude of the impedance of the tube circuit is cyclically changed at the vibrato frequency as described above, resulting in the desired deviation of the frequency of the output from the input. The operation of this phase shift bridge and of various alternative forms thereof is described in greater detail in my aforesaid copending application. Of course, the present invention is not restricted to any particular type of vibrato unit and any of the presently known vibrato units as well as those developed in the future may be utilized.

Although exemplary embodiments of the invention have been disclosed and discussed, it will be understood that other applications of the invention are possible and that the embodiments disclosed may be subjected to various changes, modifications and substitutions without necessarily departing from the spirit of the invention.

I claim:

1. In an electrical music system for operation from a signal source, the combination of: a first audio channel including a sound reproducer and having an audio pass band; a second audio channel including a sound reproducer and having substantially the same audio pass band; a vibrato unit for coupling said source to said first channel; means for coupling an A.C. control voltage to said vibrato unit in controlling relationship with the frequency of said control voltage being low relative to the low ends of said pass bands; and a low reflection, audio delay unit for coupling said first channel to said second channel in driving relationship, said delay unit providing a delay in the signal coupled therethrough in the order of one-half the period of said frequency.

2. In a device for use in a musical instrument having a signal source and a pair of reproducing systems, the combination of: a vibrato unit having an input and an output; means for coupling the signal source of the musical instrument to the input of said vibrato unit; means for coupling the output of said vibrato unit to one of the reproducing systems; a control unit for generating a control signal which cyclically varies in magnitude at a predetermined rate; means for coupling said control signal to said vibrato unit in controlling relationship; and a low reflection, audio delay unit for coupling an audio signal from said one reproducing system to the input of the second of said reproducing systems, said delay unit producing a delay in said audio signal approximately equal to one-half the period corresponding to said predetermined rate.

No references cited.

ARTHUR GAUSS, *Primary Examiner.*