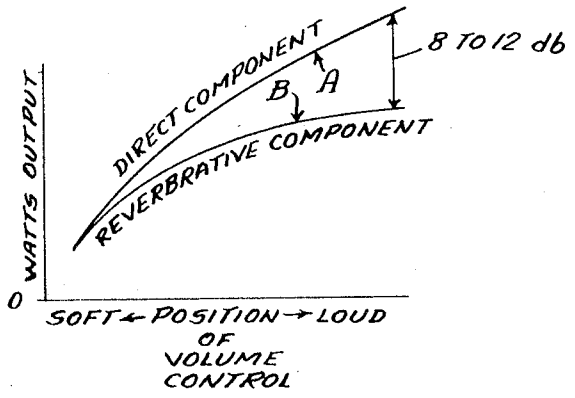
Aug. 26, 1969 H. LAUBE 3,463,868

ELECTRIC MUSICAL INSTRUMENT REVERBERATION NONLINEAR CONTROL SYSTEM

Filed June 2, 1966 2 Sheets-Sheet 1

Fig. 1.



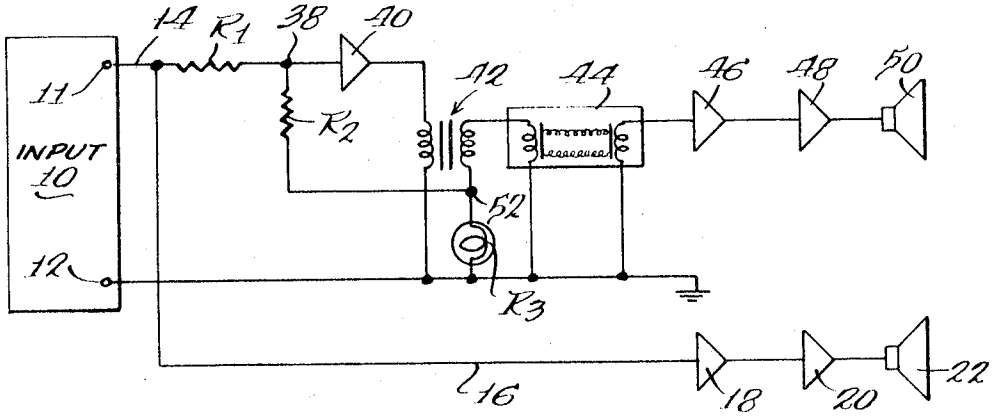


Fig. 2.

Inventor:
Hans Laube
By
Gradolph, Love, Rogers & VanSciver
Atty's

Aug. 26, 1969 H. LAUBE 3,463,868

ELECTRIC MUSICAL INSTRUMENT REVERBERATION NONLINEAR CONTROL SYSTEM

Filed June 2, 1966 2 Sheets-Sheet 2

Fig. 3.

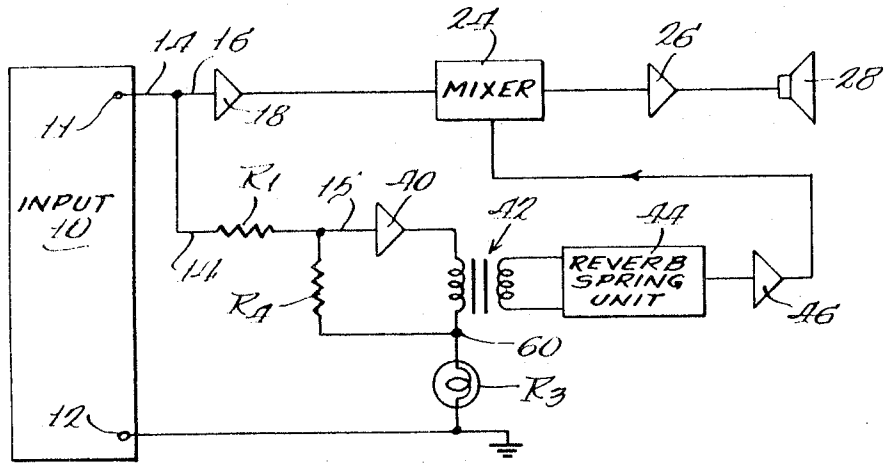


Fig. 3a.

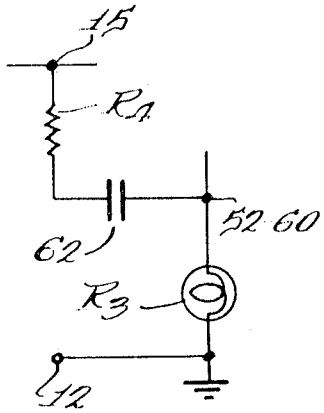


Fig. 3b.

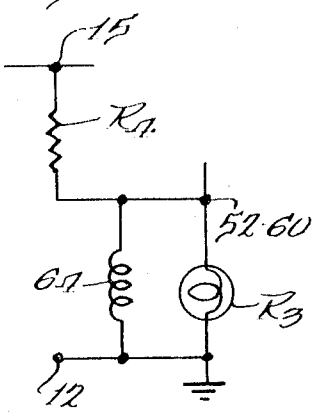
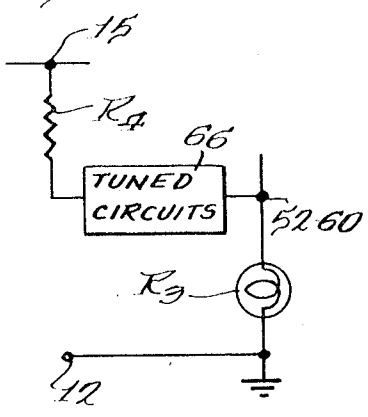


Fig. 3c.



Inventor:
Hans Laube

By

Gradolph, Love, Rogers & Van Soiver
Attys

United States Patent Office 3,463,868
Patented Aug. 26, 1969

3,463,868

ELECTRIC MUSICAL INSTRUMENT REVERBERATION NONLINEAR CONTROL SYSTEM

Hans Laube, Chicago, Ill., assignor to Hammond Corporation, a corporation of Delaware

Filed June 2, 1966, Ser. No. 554,727
Int. Cl. G10h 1/02
U.S. Cl. 84—1.24 5 Claims

ABSTRACT OF THE DISCLOSURE

A control system for proportioning an artificial reverberation signal relative to the main signal of an electrical musical instrument in which a nonlinear element is connected to receive the main signal and develops a nonlinear control signal thereacross which is fed back in inverse phase to reduce the gain of the reverberation signal nonlinearly as the level of the main signal increases.

This invention relates generally to acoustic systems and apparatus and more particularly to an artificial reverberation control system. Primarily, it is intended for organ use, but it may also be used to advantage with music reproducing systems such as record players and tape recorders, for instance.

In general, the invention contemplates controlling the relative amount of artificial reverberative effect dependent upon the loudness of the sound being produced. It has been generally recognized (see patents referred to hereinafter) that as the volume level of the music increases, the reverberation effect should not increase proportionately. More recently it has been discovered that for optimum regulation of this phenomenon it is necessary to provide a regulatory system which permits of considerable nonlinearity in its control function. The purpose of this invention is not to dictate just what nonlinearity curves should be followed, but to provide a system which frees the designer to introduce the nonlinearities which seem best to him under the circumstances. The nonlinearities contemplated include not only general signal level, but also frequency discrimination and the like as will appear.

This invention constitutes an improvement over the reverberation systems disclosed by Hammond Patent No. 2,949,805 and Hanert Patent No. 3,070,659, in which the output to a reverberation speaker does not rise as much as the output of the main speaker when the total signal increases in amplitude. Similarly, in Meinema Patent No. 3,037,414 there is disclosed an artificial reverberation control apparatus in which a nonlinearly attenuated signal derived from the direct output speaker is used to drive a reverberation amplifier. In the present system, as in these other systems, the output of the reverberation amplifier increases less than does the output to the direct speaker when the total signal level rises, but much greater and more precise control over the ultimate result is afforded by the present invention.

In this invention the amount of reverberation is automatically related to loudness of the signal in the reverberation channel. For any desired volume or intensity level the amount of reverberation in the total sound is automatically set at an optimum without effort on the part of the organist who is producing the music. For loud audio signals the proportion of reverberation in the total signal is automatically reduced; for soft signals the intensity of

the reverberating component relative to the non-reverberating component is very considerably increased, and the degree of nonlinearity of this effect is easily controllable by the designer, and, as will be seen presently, other nonlinearities can easily be introduced into the system if desired.

In general, the desirable result is accomplished by a feedback system in which a nonlinear resistor with a positive resistance coefficient is placed in the input to a reverberation unit, and the signal voltage developed across this resistance is returned to the input of a reverberation amplifier on an inverse feedback relationship. Other voltage dividers or nonlinear systems are used in the circuit as required, but the important thing is that the amount of the inverse feedback signal voltage is nonlinear with respect to the amplifier output so that the gain of the reverberation amplifier is progressively decreased as the signal increases.

One of the objects of the present invention is to provide an improved means for controlling the amount of reverberation so that it is substantially optimum for any desired signal or sound intensity level.

A further object of the present invention is to provide an improved reverberation control system wherein a feedback signal is developed across a nonlinear element and used to inversely control the intensity of a reverberation output signal.

A further object of this invention is to provide a simple and inexpensive apparatus for automatically accomplishing reverberation level control.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a chart illustrating generally the objects and results achieved by the invention;

FIG. 2 is a partial schematic and block diagram illustrating the invention;

FIG. 3 is a partial schematic and block diagram showing a modification of the invention; and

FIGS. 3*a*, 3*b*, and 3*c* show modifications which can be incorporated into the circuits of FIGS. 2 or 3.

Referring to FIG. 1, there is shown on a logarithmic scale the desired output in watts from the direct speaker and the reverberation speaker in terms of the position of the swell pedal of an electric organ or output control of some other electrical musical signal source. Curve A represents the direct signal and is approximately a straight line, while the curve B represents the reverberative portion of the signal. These curves show that at low wattage output the intensity of the reverberative component is about the same as the direct signal and rises generally along with an intensity rise of the direct component, but that at the loud end of the scale a change in the intensity of the main signal is accompanied by only a small change in the level of the reverberative component. In a particular practical system, for instance, at the maximum open position of the swell pedal the intensity of the reverberative component of the sound is approximately 8 to 12 db (decibels) lower than that of the direct signal.

In FIG. 2 the source of the sound in the form of an electrical signal is represented by a block **10**. This source may be an electric organ generating system, a phonograph, a pickup of music recorded on magnetic tape, or other similar means. The output terminals **11** and **12** are respectively connected to an output conductor **14** and

ground. Also connected to terminal **11** is a conductor **16** which leads to a direct signal preamplifier **18**, a direct signal power amplifier **20** supplied by the direct signal preamplifier and a direct signal speaker **22** supplied by the power amplifier.

Conductor **14** leads through resistor R1 to the input terminal **38** of a reverberation driver amplifier **40**. The primary of an impedance matching transformer **42** is connected from the output of the reverberation driver amplifier **40** to ground. The secondary of the transformer **42** is connected at one side to ground through the driver element of a reverberation spring unit **44**, whereas the other side of the secondary, represented by terminal **52**, is connected to ground through a reverberation drive current sensing resistor R3.

Connected in series with the output of the reverberation unit **44** are, in order, a reverberation recovery amplifier **46**, a reverberation power amplifier **48**, and a reverberation speaker **50**. A reverberation unit of the type contemplated at **44** forms the subject matter of Meinema et al. Patent No. 2,982,819. A feedback resistor R2 is connected between transformer terminal **52** and the input terminal **38** of the reverberation driver amplifier **40**. Resistors R1 and R2 act as negative feedback voltage dividers, and adjustment of their values will determine the effectiveness of the fed back voltage in reducing the gain. The reverberation drive current sensing resistor R3 is a nonlinear device, such that its resistance increases with increased current in the transformer secondary circuit. For this purpose it is preferred to use an inexpensive small light bulb of the type suggested in the previously referred to Patent No. 3,037,414. As the current increases, the light bulb glows more brightly and its resistance increases, since such incandescent lights have a positive temperature coefficient of resistance. Thus, an increase in signal current increases the resistance at R3 and increases nonlinearly the feedback signal through R2 to the input of amplifier **40**. Since the fed back signal is phased oppositely with respect to the signal from source **10**, the gain of amplifier **40** is reduced with an increase in the signal level. By proper selection of the negative feedback voltage divider resistors R1 and R2, and the characteristics of R3, and the basic gain of amplifier **40**, just about any desired shape of the function output current versus input signal level can be achieved. In the particular embodiment shown, the output current versus input signal level is adjusted to achieve approximately the response shown in FIG. 1.

FIG. 3 is a modification of the invention shown in FIG. 2. Here, there is a single output speaker **28** as opposed to the two channel output shown in FIG. 2. The tone signal input, which has a variable intensity, is supplied from block **10**, and terminals **11** and **12**, as in FIG. 2. These terminals are respectively connected to a connector **14** and to ground. Connector **14** is connected through a resistor R1 to the input **15** of a reverberation driver amplifier **40**, the output of which is connected through the primary of transformer **42** to ground through a small light bulb which acts as a nonlinear series resistor R3. A terminal **60** between the transformer primary and resistor R3 is connected through resistor R4 back to the amplifier input at **15**.

The secondary of transformer **42** is connected to drive the reverberation spring unit **44**. The input of a reverberation recovery amplifier **46** is connected to the output of the reverberation spring unit **44**, and the output therefrom is connected to a linear mixer **24** which combines the signals from the direct output preamplifier **18** and the reverberation recovery amplifier **46**. The output from linear mixer **24** is connected to a power amplifier **26** which in turn is connected to an output speaker **28**. The operation of the embodiment shown in FIG. 3 is similar to that of FIG. 2 in that the current sensitive nonlinear resistor R3 feeds back a nonlinear out of phase voltage which increases nonlinearly with an increase in signal from the source **10**, thus reducing the gain of amplifier **40** upon an increase in signal amplitude.

Note that with either of these circuits the nonlinear resistor R3 has a dual effect upon the character of the curve B of FIG. 1. First, an increase in signal current increases the resistance of R3, and this has a direct effect upon the series connected reverberation unit; that is, the resulting increase in impedance of the reverberation unit input circuit will reduce the current therethrough and have a signal compressing effect. This is the sole effect taught in previously mentioned Meinema Patent No. 3,037,414. The second effect is cumulative and is the result of inverse feedback of the signal developed across nonlinear resistor R3 to the amplifier input. An important advantage of the present circuit is not only that it increases the compression effect as compared with Meinema, but that the feedback path lends itself well to additional control, such as that established by the resistors R1 and R4, which can be adjusted to change curve B of FIG. 1.

The feedback path can also be used to introduce additional nonlinearities if desired. As an example, if it is wished to compress the high frequencies more than the low frequencies upon a signal increase, a capacitor **62** (FIG. 3*a*), of appropriate value, can be connected in series with R4 so as to remove some of the low frequencies from the inverse signal fed back to the amplifier input. A choke **64** (FIG. 3*b*), connected from terminal **52** or **60** to ground, would accomplish much the same effect. Other arrangements for obtaining special effects will suggest themselves and may make various uses of capacitors, chokes, resistors, and/or tuned circuits **66** (FIG. 3*c*). The important consideration is that the basic circuit provides a system which facilitates the introduction of various nonlinear elements to produce special effects.

Summarizing, the invention contemplates using a nonlinear resistor with a positive resistance coefficient or its equivalent in the drive line to the reverberation unit, and feeding back the voltage developed across the nonlinear element to the input of the reverberation amplifier on an inverse phase relationship. Thus the amount of the inverse feedback voltage is nonlinear, whereby the gain of the reverberation amplifier is decreased as the signal volume rises.

In addition, it is contemplated to provide frequency discrimination by means of capacitors, inductors, and/or resonant circuits connected so as to affect the fed back signal.

Various modifications may be made in the invention without departing from the spirit and scope thereof, and it is desired, therefore, that only such limitations shall be placed thereon as are imposed by the prior art and are set forth in the appended claims.

I claim:

1. A reverberation control system comprising a source of musical tone signals of changeable amplitude, means to transduce said signals, an amplifier having an input connected to receive said source signals, a reverberation apparatus, means coupling the output of said amplifier to the reverberation apparatus input, means to transduce the output of said reverberation apparatus, said coupling means including a nonlinear impedance element, means inversely to feed back the nonlinear signal developed across said nonlinear element to the input of said amplifier to reduce the effective gain of said amplifier nonlinearly as the amplitude of said source signal increases.

2. In a reverberation control system, the combination recited in claim **1** wherein said nonlinear element is a current sensitive resistor.

3. In a reverberation control system, the combination recited in claim **1** wherein said inverse feedback circuit includes means for introducing an additional nonlinearity into the inverse signal fed back to said amplifier input.

4. In a reverberation control system, the combination recited in claim **4** wherein said inverse feedback circuit

includes reactive means to discriminate the inverse feedback signal on a frequency basis.

5. In a reverberation control system, the combination recited in claim 1 including, means providing a mixer circuit connected to combine the output signals from said source with the output signals from said reverberation apparatus.

References Cited

UNITED STATES PATENTS

2,811,591	10/1957	Kennedy.	
2,949,805	7/1960	Hammond	84—1.24
3,037,414	6/1962	Meinema	84—1.24
3,070,659	12/1962	Hanert	84—1.24 X
3,267,197	7/1966	Hurvitz	84—1.24

HERMAN K. SAALBACH, Primary Examiner

S. CHATMON, JR., Assistant Examiner

U.S. Cl. X.R.

84—1.27