March 4, 1969 N. GONCHAROFF 3,431,358

SOUND REPRODUCING SYSTEM

Filed Aug. 12, 1965

FIG. 1

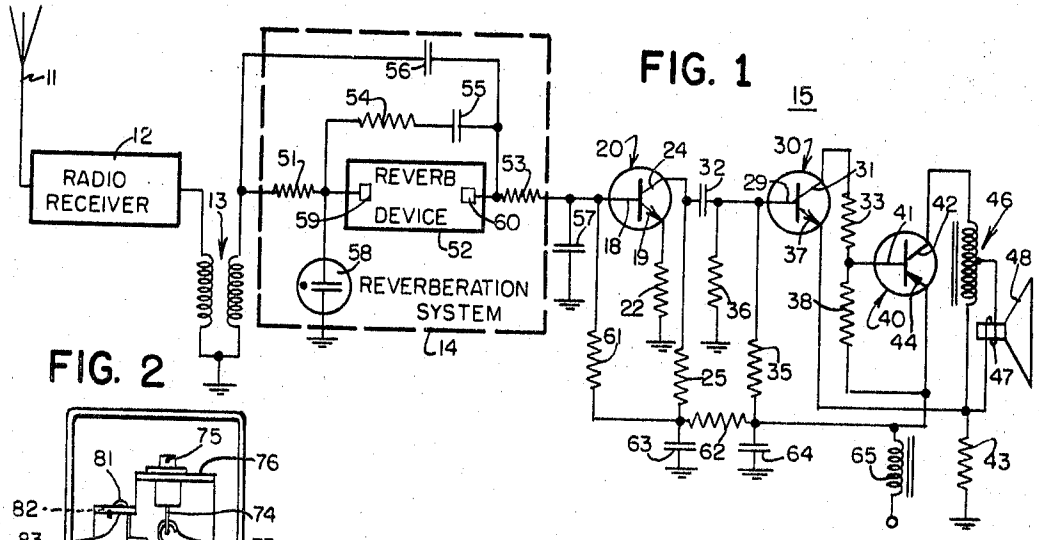


FIG. 2

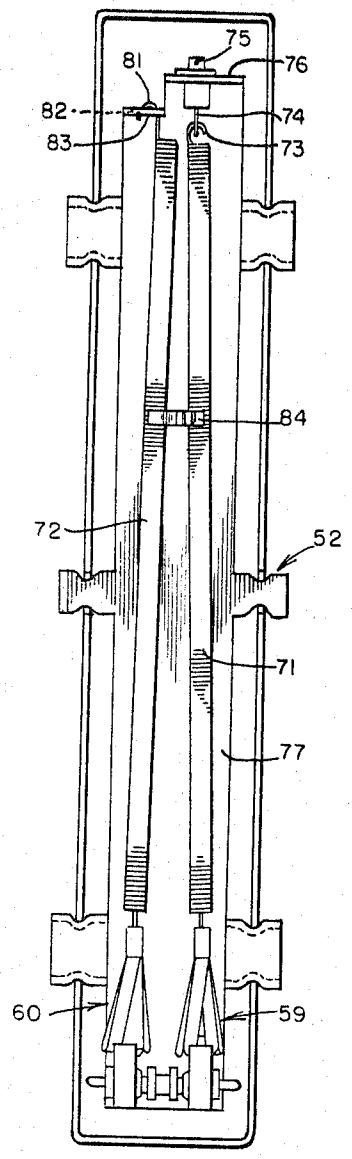


FIG. 3

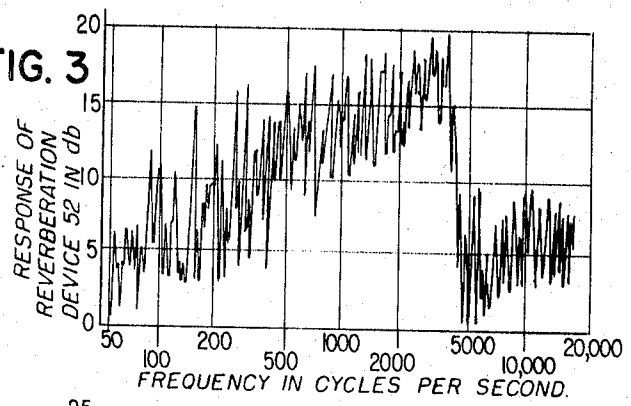
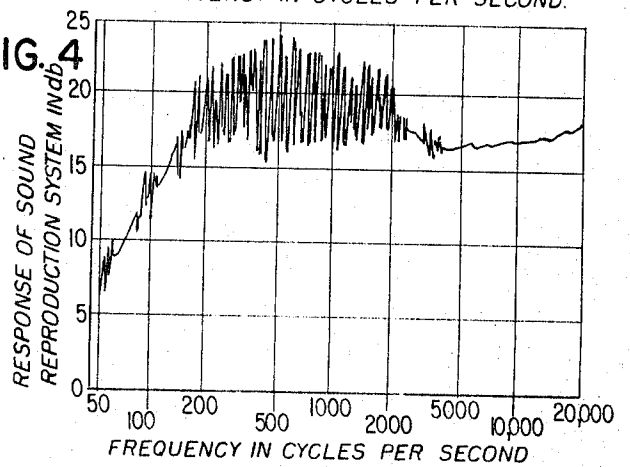


FIG. 4



INVENTOR
NIKOLAI GONCHAROFF

BY
Mueller, Aichele & Rauner

ATTYS.

United States Patent Office 3,431,358
Patented Mar. 4, 1969

3,431,358

SOUND REPRODUCING SYSTEM

Nikolai Goncharoff, Roselle, Ill., assignor to Motorola, Inc., Franklin Park, Ill., a corporation of Illinois

Filed Aug. 12, 1965, Ser. No. 479,218
U.S. Cl. 179—1 6 Claims
Int. Cl. H04m 1/00; H02h 7/20, 3/28

ABSTRACT OF THE DISCLOSURE

Sound reproducing apparatus including a reverberation device having a positive slope up to a given frequency and a lesser response above this frequency, with a filter bypassing the reverberation device and passing signals in the range of speech and above the given frequency. The signals from the reverberation device and the filter are applied to an amplifier which has characteristics such that the amplifier output is substantially flat. A neon bulb at the input to the reverberation device protects the input transducer thereof and a noise filter at the amplifier input attenuates high frequency noise superimposed on the audio signal to be reproduced.

This invention relates to apparatus for the reproduction of sound, and more particularly to a reverberation sound system.

It may be desirable under certain circumstances to add to sound reproduction delayed signals of decaying amplitude to simulate the reverberation effect produced in a concert hall. The delayed signals may be produced by a mechanical vibrating delay device. Such signals may enhance the quality of the sound being reproduced by artificially prodcing the reflection and diffusion of sound, as is normally found in a concert hall, and which may be lacking in the room or enclosure in which the sound is being reproduced. Such reverberation will produce a subjective enlargement of the room or enclosure and add depth and dimension to the sound being reproduced.

Sound reproduction apparatus which includes a sound reverberation system may present a difficulty in that the reproduction of human speech, as the addition of the delayed signals may result in sound which is garbled or even unintelligible. Although the reverberation system might be switched out when human speech is present, this results in complex equipment, or in a manual control which may be an inconvenience to a listener.

A further difficulty with reverberation devices which use mechanical vibrating delay lines or devices is that such delay lines may change their mode of vibration above a certain frequency. This causes the frequency response of the unit to fall off drastically, which may be very unsatisfactory from the audio reproduction standpoint.

Another problem encountered with reverberation devices is that the input transducer for converting the input electrical signals into mechanical vibrations may be quite delicate and subject to damage by excessive voltages. This may cause failure of the device and require a costly repair.

It is an object of this invention to provide an improved sound reverberation system in which the clarity of human speech is enhanced.

Another object of the invention is to minimize the effect of a change in mode of vibration of a reverberation device in a reverberation system.

Still another object of the invention is to provide sound reproduction apparatus having a reverberation device wherein the apparatus exhibits a generally flat response characteristic over a wide range of frequencies.

A further object of the invention is to provide a reverberation system wherein the input tranducer of the reverberation device is protected from excessive voltages.

A feature of the invention is the provision of a sound reverberation system wherein a shunt path bypasses varying amounts of direct sound around a reverberation device to supply unreverberated sound in the frequencies of human speech.

Another feature of the invention is the provision of a sound reverberation system wherein a filter bypasses direct sound around the reverberation device to compensate for frequency response fall off when the reverberation device changes its mode of vibration.

A further feature of the invention is the provision, in a sound reverberation system having a reverberation device, of a neon bulb connected to the reverberation device, and which breaks down to chunt current therefrom when the driving voltage exceeds a given level to prevent damage to the input transducer of the reverberation device.

In the drawings:

FIG. 1 is a schematic diagram of the sound reproduction portions of a radio receiver which incorporates a sound reverberation system in accordance with the invention;

FIG. 2 is a plan view of the reverberation device of FIG. 1;

FIG. 3 is a graph illustrating the frequency response characteristics of the reverberation device of FIG. 2; and

FIG. 4 is a graph illustrating the frequency response characteristic of the sound reproduction portions of FIG. 1, as shown.

In accordance with the invention, sound reproduction apparatus is provided including an amplifier exhibiting a generally negative slope response characteristic, to which signals are provided by a reverberation device which produces an output comprised of delayed signals of decaying amplitude and by a circuit providing audio frequency signals without delay. The reverberation device exhibits a generally positive slope frequency response characteristic over a given frequency range, which may extend from about 50 to 5,000 cycles. A shunt path for audio frequency signals bypasses the reverberation device so that audio frequency signals which are not delayed are combined with the output of the reverberation device. The components of the shunt path are selected to be of a value to bypass relatively large amounts of signals in the frequency range of human speech.

The frequency response of reverberation devices may drop off substantially above a frequency which may be in the range above 5,000 cycles, due to a change in the mode of vibration of the device. To compensate for this, a filter may be provided to bypass around the reverberation device signals which exceed the given frequency, so that the reverberation system response curve is brought up to a substantially flat level. As further refinements to the circuit, a noise filter may be provided and a neon bulb may be connected on the input side of the reverberation device to protect the input transducer of the device from excessive voltages.

In FIG. 1, a schematic diagram of sound reproduction apparatus incorporating the invention is shown. The apparatus shown is for the reception of radio signals and their reproduction as sound, and might be used, for example, in an automobile. Radio signals received by antenna **11** are converted in radio receiver **12** to audio frequency signals. Such signals are then applied through a transformer **13** to a sound reverberation system **14**. Reverberation system **14** produces delayed signals of decaying amplitude to produce a concert hall effect in the sound signals to be reproduced. In other words, the echoes and reflections ordinarily found in a large room or concert

hall but which may be lacking, for example in an automobile enclosure, are added to the signal artificially to give the reproduced sound depth and dimension.

The reverberation system **14** adds delayed signals of decaying amplitude to the sound to be reproduced. The reverberation system **14** includes a main current path comprised of resistor **51**, reverberation device **52** and resistor **53**. Reverberation device **52** is of the mechanical delay line type wherein a pair of transducers, one for the input and one for the output, respectively drive and receive signals through one or more resilient members which vibrate in a particular mode. A particular device which may be used in the system of the invention is shown in FIG. 2 and is described in the copending application of Hugo Schafft, Ser. No. 324,638, filed Nov. 19, 1963, and assigned to the assignee of the present invention. The reverberation device shown in FIG. 2 exhibits a generally positive slope frequency response characteristic. This may be seen from FIG. 3 wherein the trend of the frequency response excursions is generally upwards with frequency, up to a frequency of about 5,000 cycles per second.

As seen in FIG. 2, reverberation device **52** includes a pair of helical delay springs **71** and **72**, coupled at one end thereof to transducers **59** and **60**, respectively. Transducer **59** imparts a torsional vibration to spring **71** which is transmitted to spring **72** and received by transducer **60**. The springs **71** and **72** are wound in opposite directions, so that the effect of outside vibrations thereon is virtually cancelled out. Reflective means are provided for suspending the ends of the springs **71** and **72** opposite the transducers. Spring **71** is provided with a hook **73** connected by a length of string **74** to the terminal **75** mounted in an upwardly extending flanged end **76** of plate **77**. This suspension is effectively equivalent to an open circuit and will reflect substantially all vibrations exactly in phase. Spring **72** has a hook **81** secured in a notch **82** in an upwardly extending flange portion **83** of plate **77**. Accordingly, this end of spring **72** is rigidly secured to the mass of the plate and is effectively equivalent to a short circuit. At this end of spring **72**, substantially all the vibrations will be reflected with a phase reversal. A single link **84** is used to couple vibrations between springs **71** and **72** at respective points intermediate the mid points and the suspended ends of the springs.

In accordance with the invention, a shunt path is connected about the reverberation device **52**, and bypasses signals around the reverberation device. This shunt path is comprised of resistor **54** and capacitor **55**. The values of resistor **54** and capacitor **55** are selected such that the shunt path presents a low impedance to signals within the range of frequencies of human speech (approximately 100 to 500 c.p.s.) as compared with the impedance to such signals presented by the reverberation device **52**. Thus, a large portion of the signals in this range are made up of signals bypassed around reverberation device **52** by the filter **54–55**. The increased amount of direct sound which is bypassed in this frequency range greatly enhances the clarity of speech reproduced by the apparatus. The overall response exhibited by the reverberation system **14** is still of generally positive slope.

The output of reverberation system **14** is coupled to an audio amplifier **15**. The first stage of the amplifier comprises a transistor **20** which has a base electrode **18** and an emitter electrode **19** coupled to a reference potential by the emitter bias resistor **22**. The transistor **20** constitutes the predriver stage of the amplifier and functions to amplify the audio signals from the reverberation system **14**. The amplified signals are coupled from the collector electrode **24** of transistor **20** to the base electrode **29** of NPN type transistor **30** by the coupling capacitor **32**. A direct current potential is coupled by resistor **25** to the collector **24** to furnish collector bias for transistor **20**.

Transistor **30** constitutes the driver stage of the audio amplifier **15** and has collector **31** direct current coupled by resistor **33** to the base **41** of PNP type transistor **40**. Transistor **40** constitutes the power output stage of the amplifier. Resistor **33**, in addition to coupling the amplified audio signal to base **41**, functions to restrict the collector dissipation of transistor **30** and will protect the transistor from destruction by restricting the peak drive current to the driver stage **30** should the output load across transformer **46** become shorted. A direct current potential is coupled to the base **29** of transistor **30** by the voltage divider including resistors **35** and **36**, to provide bias therefor.

Transistor **40** has an output circuit consisting of the transformer **46** and resistor **43** connected in series and coupled between the collector electrode **42** of the transistor **40** and the reference potential. The emitter electrode **44** of transistor **40** is connected to the power supply circuit to provide emitter collector conduction and for biasing transistor **40** through a resistor **38** connected between the emitter and base thereof. In addition to biasing transistor **40**, resistor **38** assures that the base **41** will not be in an open condition should transistor **30** be removed or discharged. The power supply circuit includes resistors **61** and **62**, filter capacitors **63** and **64**, and choke **65**, connected as shown to a DC source.

The transformer **46** drives the voice coil **47** of a speaker **48**. A direct current negative feedback path is connected from the junction between transformer **46** and resistor **43** to the emitter electrode **37** of transistor **30**. The inductance **46** presents a relatively high impedance to the audio signals, while the resistor **43** presents a relatively low impedance to the same signals. The audio signal therefore develops a voltage across the transformer **46** which is coupled to the speaker **48** for the audio output. The direct current in the energizing path for the transistor **40** previously described flows through the inductance **46** and is coupled by the negative feedback path to the emitter **37** of transistor **30**. This samples the direct current from collector **42** and couples it to emitter **37**, causing the potential to increase on the emitter to back bias transistor **30**. The back biasing of transistor **30** causes the potential on the base electrode **41** of transistor **40** to increase, which back biases the transistor **40** to reduce the collector current. Shifts in the direct current operating point of transistor **40** because the temperature changes, or by placement of the transistor, are compensated by the negative feedback to stabilize the power output of the amplifier. In addition, because of the feedback used, the amplifier exhibits a negative slope frequency response characteristic. This is because, as frequency increases, the gain of the amplifier decreases.

The negative slope frequency response of the amplifier offsets the positive slope response of the reverberation system **14** such that the overall response is substantially flat as seen in FIG. 4.

Referring again to FIG. 3, it will be seen that above approximately 5,000 cycles, the frequency response of the reverberation device **52** falls off substantially. In this range, the mode of vibration of the mechanical delay lines **71**, **72** (FIG. 2) in the reverberation device **52** changes from torsional to longitudinal, causing the response to fall off. This is a characteristic of a device of a particular structural configuration and is not necessarily characteristic of reverberation devices or of devices of the type shown in FIG. 2. The decrease in response above 5,000 cycles will cause an impairment of the quality of the higher frequency sounds reproduced by the apparatus. To compensate for this, a capacitor **56** is connected from the junction between transformer **13** and resistor **51** to the junction between reverberation device **52** and resistor **53**. The value of capacitor **56** is selected to present a low impedance to signals in the critical fall off range, and raise the general response of the system to a more level configuration. The result of capacitor **56** may be seen in FIG. 4. It will be noted that the reverberation is lessened somewhat in the higher frequencies by the capacitor **56**, but it has been found that this has little detrimental effect on the overall performance of the system.

Peak noise and other such high frequency noises may be present in the system. In order to eliminate such disturbances and enhance the clarity of the reproduced sound, a capacitor **57** is connected at the output of reverberation system **14**. Capacitor **57** is of a value selected to attenuate the higher frequency noise signals which are superimposed upon the sound signals being reproduced.

The input transducer **59** for converting electrical signals into mechanical vibrations may be sensitive to high voltages, and the transducer utilized in the particular reverberation unit shown in FIG. 2 is of this nature. This transducer includes a ceramic bimorph which is susceptible to damage by voltages exceeding a given level. In order to protect the input transducer from such voltages, a neon bulb **58** connects the input of reverberation device **52** to a reference potential. The break down level of neon bulb **58** is selected such that the bulb will break down before the voltage at the input of reverberation device **52** attains a dangerous level. Once the bulb breaks down, the system produces sufficient noise that the speaker **48** will provide an audible warning to the driver to turn down the volume control of receiver **12**.

All the elements of the reverberation system **14** will affect the system performance to some extent. For example, the values of the resistors or capacitors in reverberation system **14** affect system sensitivity and system response. Furthermore, resistors **51** and **54** and capacitors **55** and **56** affect the decay time of the reverberation system. The delay time of the reverberation system is affected by resistor **54** and capacitors **55** and **56**. Resistor **53** reduces distortion in the apparatus by preventing clipping of the high amplitude signals.

A practical system has been constructed wherein the reverberation system **14** included elements having the following values for a 100 microvolt sensitivity level:

Resistor **43**	ohms	0.6
Resistor **51**		100K
Resistor **53**		390K
Resistor **54**		8.2M
Capacitor **55**	picofarads	15
Capacitor **56**	do	6.8
Capacitor **57**	microfarads	.0033

Such values of resistor **54** and capacitors **55** and **56** provided the desired action in the frequency response. Other values to attain the desired action can be selected by one skilled in the art in accordance with the teaching of this invention.

It may therefore be seen that the foregoing invention provides a reverberation system in which the reproduction of human speech is significantly clarified. The overall response is made substantially level and the effect of vibration mode change in the reverberation device is minimized. Protection is afforded for the input transducer of the reverberation device, and noise is substantially reduced.

I claim:

1. A sound reverberation system including in combination, a reverberation device having an input for receiving audio frequency signals and an output for producing delayed signals of decaying amplitude, said reverberation device having a response which increases with frequency over a frequency range extending to a given frequency and a substantially lesser response above said given frequency, filter means connected to said reverberation device and providing a shunt path for audio frequency signals to bypass said reverberation device, said filter means having a first portion for bypassing signals in the frequency range of human speech and a second portion for bypassing signals above said given frequency, and amplifier means connected to said reverberation device and to said filter means to amplify the bypassed audio frequency signals and the signals at the output of said reverberation device, said filter means and said amplifier means having characteristics to complement the response of said reverberation device and produce a substantially flat overall response at the output of said amplifier means.

2. The combination of claim **1** wherein said first portion of said filter means comprises resistance means and capacitance means in series, and said second portion thereof comprises capacitance means.

3. A sound reverberation system including in combination, a reverberation device having an input for receiving audio frequency signals and an output for producing delayed signals of decaying amplitude, said reverberation device having a response which increases with frequency over a frequency range extending to a given frequency and including the frequencies of human speech, and a lesser response above said given frequency, filter means connected from said input to said output of said reverberation device and including first and second portions providing shunt paths for audio frequency signals to bypass said reverberation device, said first portion having a response to bypass signals in the frequency range of human speech to increase the intelligibility thereof, said second portion having a response to bypass signals above said given frequency, and amplifier means connected to said reverberation device and to said filter means to amplify bypassed audio frequency signals and signals at the output of said reverberation device, said amplifier means having a response which decreases with frequency and which cooperates with the response of said reverberation device and of said portions of said filter means to produce a substantially flat overall response at the output of amplifier.

4. A sound reverberation system including in combination, audio frequency signal supply means, amplifier means, a reverberation device having an input and an output for producing delayed signals of decaying amplitude, said reverberation device exhibiting a generally positive slope response characteristic over a first frequency range and exhibiting a substantially diminished response within a second frequency range including higher frequencies than said first frequency range, said first frequency range including the frequency range of human speech, a first resistor connecting said audio frequency signal supply means to said reverberation device for supplying signals thereto, a second resistor connecting said reverberation device to said amplifier for supplying the output of said reverberation device thereto, a third resistor and a first capacitor series connected from the junction between said first resistor and said reverberation device and the junction between said reverberation device and said second resistor, a second capacitor connecting the junction between said audio frequency supply means and said first resistor to the junction between said reverberation device and said second resistor, a third capacitor connecting the junction between said second resistor and said amplifier means to a reference potential for attenuating high frequency noise signals, said third resistor and said first and second capacitors providing filter circuits for bypassing said reverberation device, said filter circuits and said amplifier having response characteristics to complement the response characteristic of said reverberation device and produce an overall response characteristic of generally zero slope extending over said first and second frequency ranges.

5. A sound reverberation system including in combination, a reverberation device having an input for receiving audio frequency signals and an output for producing delayed signals of decaying amplitude, said reverberation device having a response which increases with frequency over a frequency range extending to a given frequency and including the frequencies of human speech, and a lesser response above said given frequency, filter means connected from said input to said output of said reverberation device and having response characteristics to bypass signals in the frequency range of human speech to increase the intelligibility thereof, and to bypass signals above said given frequency, and amplifier means connected to said reverberation device and to said filter means

to amplify signals at the output of said reverberation device and signals bypassed by said filter means, said amplifier means having a response which decreases with frequency and which cooperates with the response of said reverberation device and of said filter means to produce a substantially flat overall response at the output of said amplifier.

6. A sound reverberation system in accordance with claim 5 wherein said reverberation device has an input transducer subject to damage from input voltages exceeding a given level, and including a neon bulb coupled to said input of said reverberation device having a breakdown voltage which is less than said given level to shunt current from said reverberation device and protect said input transducer thereof.

References Cited

UNITED STATES PATENTS

1,477,668	12/1923	Schröter	317—57 XR
2,230,836	2/1941	Hammond	179—1
2,671,874	3/1954	Friedrichs	317—31
2,852,604	9/1958	MacCutcheon	179—1
2,942,070	6/1960	Hammond	179—1 XR

KATHLEEN H. CLAFFY, *Primary Examiner.*

R. P. TAYLOR, *Assistant Examiner.*

U.S. Cl. X.R.

317—31, 51