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Dugan

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[54] **CONTROL APPARATUS FOR SOUND REINFORCEMENT SYSTEMS**

[76] Inventor: **Daniel E. Dugan,** 3715 22 St., San Francisco, Calif. 94114

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[51] **Int. Cl.** **H04r 27/00**

[58] **Field of Search** .... 179/1 VC, 1 VL, 1 AT, 1 B, 179/1 P, 1 CN, 1 H, 1 A

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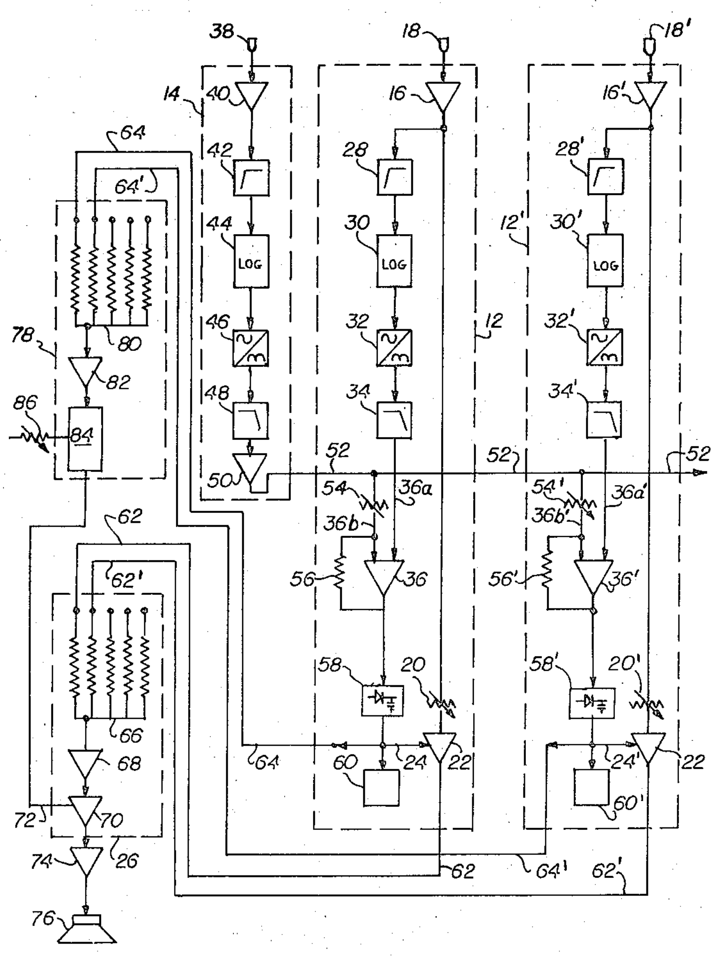
Primary Examiner—Kathleen H. Claffy
Assistant Examiner—Douglas W. Olms
Attorney, Agent, or Firm—Julian Caplan

[57] **ABSTRACT**

A control apparatus for a sound reinforcement system having plural audio input program microphones installed in a theater or like environment. The ambient sound or noise level in the environment is sensed and is employed to control each microphone individually so that a microphone is activated only if the audio material impinging thereon exceeds the ambient noise level. The audio output of the entire system is continuously and automatically adjusted so that the gain or amplification to which audio program signals are subjected is proportional to the number of program microphones that are active, thereby optimizing the operation of the system.

10 Claims, 1 Drawing Figure



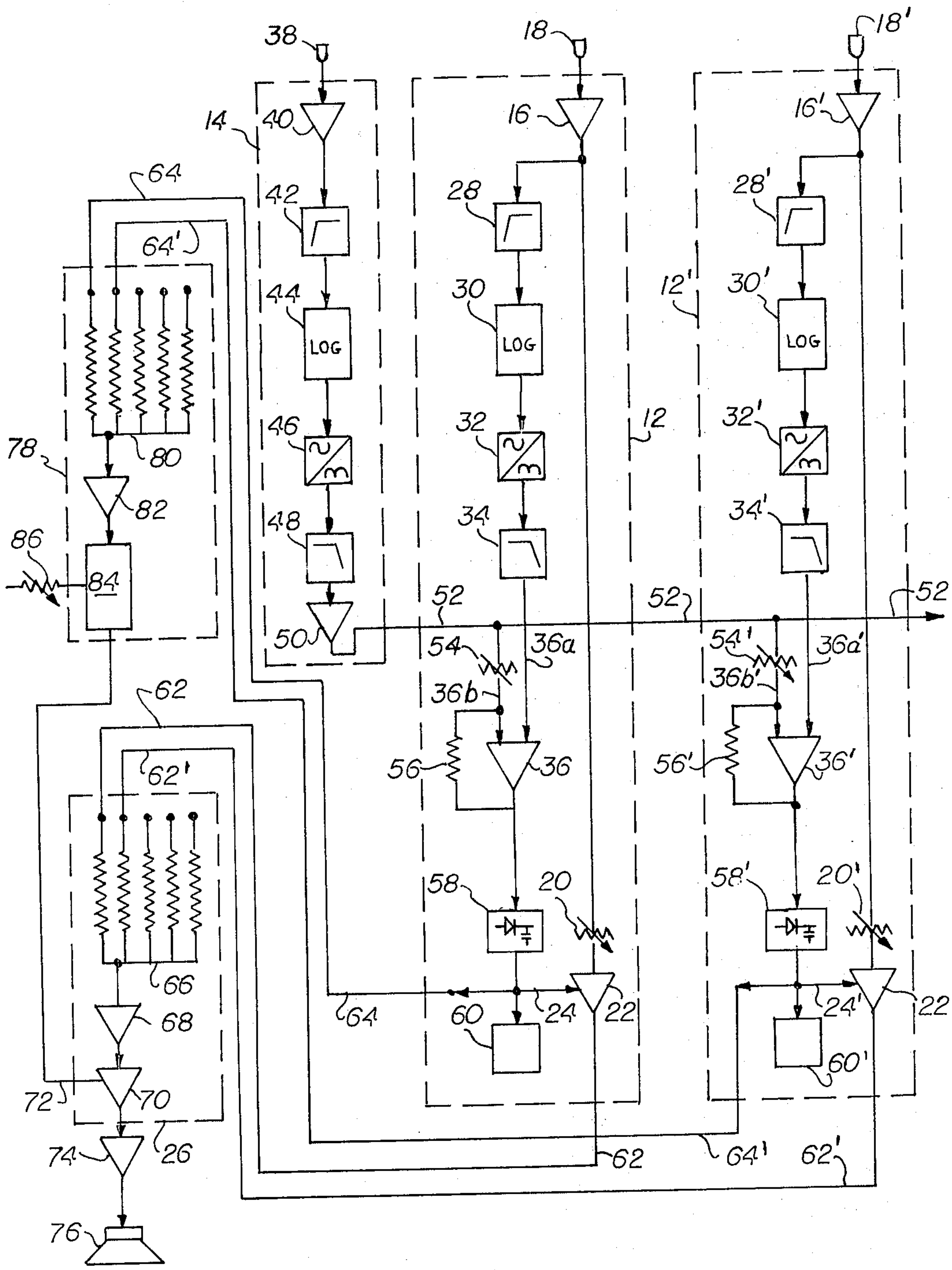

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Fig. 1

CONTROL APPARATUS FOR SOUND REINFORCEMENT SYSTEMS

This invention relates to the art of sound reinforcement in meeting halls, churches, legislatures, theaters, concert halls and other places where sound is reinforced by the use of plural microphones, amplifiers and loudspeakers. More particularly, it relates to an improved control apparatus which eliminates some of the disadvantages of multiple-microphone systems. More particularly still, this invention relates to a microphone mixer system that can switch multiple microphones on and off automatically in response to wanted and unwanted sounds, and also adjust the gain of all the microphones to achieve the maximum gain possible for the number of microphones in use at any moment.

Increasing dependence upon sound reinforcement systems in places of assembly has necessitated the use of greater numbers of microphones in these systems. As more microphones are used in systems, two problems characteristic of multiple-microphone systems have become more prominent. First, such systems are subject to objectionable pickup of ambient noise and reverberation. For example, if a person speaks near one microphone, all the other open microphones in the system pick up ambient noise and the reverberations of both the speaker's voice and the loudspeakers. Second, the amount of gain obtainable from any microphone in a system before acoustical feedback occurs is reduced in proportion to the number of microphones open, to the point where a system having plural microphones must have an operator fading microphones up and down in order to provide any useful amount of gain. In most applications of reinforcement systems it is not practical to have an operator present. When reinforcement is provided for a panel discussion, for example, it is necessary to have a live microphone in front of each panelist, and the number of open microphones reduces the gain of the system severely. In many musical and theatrical applications, the action is too fast for even a skilled operator to follow, so that even with an operator, several microphones must be open much of the time. In legislatures and meetings, the necessity for a sound operator to react to the need for a microphone to be on, identify the microphone, and turn it up before a person can speak is often an obstruction to the efficiency of proceedings. Churches often need to have three or more microphones at different locations, and maximum gain is needed at each location.

Clearly, there is a need for a sound reinforcement system which automatically keeps microphone channels attenuated except when they are needed and which automatically adjusts gain to maximize gain under differing conditions. The present invention provides such a system.

A principal object of this invention is to provide a means by which multiple microphones can be utilized in a sound reinforcement system without incurring the disadvantages of increased ambient noise pickup and reduced gain.

A further object of this invention is to provide means by which sound reinforcement systems having any number of microphones can be operated automatically with maximum gain available at each microphone.

A still further object of this invention is to provide a means for reducing the ambient noise and reverberation pickup of a sound reinforcement system by automatically and silently gating microphones on and off in response to the signal-to-noise ratio existing at each microphone.

A still further object of this invention is to provide a means by which the gain of a multiple-microphone reinforcement system utilizing switching of microphones can be maximized automatically in accordance with the number of active microphones.

Another object of this invention is to provide the above-mentioned features in a device which is easy to install and operate, requiring no special wiring and usable with all other standard sound system components.

Yet another object of the present invention is to provide a sound reinforcement system for a plurality of microphone inputs which affords automatic feedback suppression. This object is achieved by a system made according to the present invention; should self-oscillation occur, it will be sensed as noise by the system and the offending microphone or microphones will be shut off automatically.

The embodiment of this invention that is described in detail hereinbelow includes a microphone mixer system that has an individual input channel for each of the microphones in the system. The mixer system also has an input for a reference or noise-sampling microphone. There is a channel associated with the reference or noise sampling microphone input which establishes a threshold signal that is supplied to each of the program channels. The apparatus is arranged so that a given program channel will not transmit until the level of the program material therein exceeds the noise threshold. For this purpose, each channel has a DC comparator that compares the envelope of the program material in that channel with the envelope of the noise level and produces a gating signal only when the level of the program material exceeds the level of noise.

Each of the program channel outputs is connected to a summing amplifier which sums the audio signals from whichever channels are gated on into a single mixed signal channel which then goes into a voltage-controlled amplifier for gain adjustment.

To effect the adjustment of gain relative to the number of microphone channels open, a summing amplifier sums the outputs of the channel comparators. This results in a voltage which increases step-wise according to the number of microphones open. This voltage is processed by a DC function generator to produce an appropriate control voltage for the voltage-controlled amplifier in the audio output channel.

The mixer is installed as though it were a conventional mixer, except for the addition of the reference microphone, which is positioned to pick up a general balance of sound in the area of the program microphones. A sensitivity control is provided to adjust the switching threshold of each program microphone channel. This is set just below the point at which ambient noise would cause the microphone to switch on. Each microphone will then automatically switch on instantaneously whenever it is in the direct sound field of a sound source, but will remain off to distant or off-mike sources, as switching is actuated by the difference between the envelopes of the signal and reference microphone channels. To aid the operator in adjusting the sensitivity controls, an indicator light for each channel shows when the channel is in the on condition. Another special control on the mixer controls the overall "boost" function and determines the amount of system gain increase that will automatically occur when less than the maximum number of microphones is open at any time.

The audience listening to reinforced sound hears a mixture of the output of the sound system, reverberation and ambient noise. The same reverberation or ambient noise which causes a microphone to switch off also masks the perception of that switching by the audience. If it is desired to use the output of this mixer for broadcast or recording, it is necessary to mix in some ambient noise signal.

The automatic functions and operating advantages of this invention can effect a significant improvement in the performance of a sound reinforcement system in most applications. Any number of persons may participate in a panel discussion, with each having the benefit of the gain of a single-microphone sound system. When several people talk at once, gain will automatically be reduced just enough to prevent feedback. When this invention is used with a rock band, it is possible to have high-gain microphones available for the amplification of soft acoustical instruments without overloading the sound system when loud amplified instruments start to play, as unused microphones will be attenuated automatically. In a legislative chamber or convention hall, this invention makes it possible to have any number of microphones available, one for every person who may need to address the assembly, without the need for a signalling system to get the attention of a sound operator. The only wiring necessary for the installation of this type of sound system is a standard microphone cable for each microphone. When this invention is used in a church, it is possible to have microphones with maximum gain available at as many locations as are needed, with significant relief from the feedback problems usually encountered when several microphones are used in a highly reverberant space.

The principles of the invention together with additional specific objects and features thereof will be fully apprehended from the following detailed description of an illustrative embodiment and from the drawing, in which

The FIGURE is a block diagram of a microphone control system incorporating the present invention.

The system has a plurality of identical program microphone input channels, of which only two are shown in the drawing for clarity and are identified by reference numerals **12** and **12'**. In this embodiment one microphone channel **14** serves to develop the reference or noise signal by which the automatic attenuation threshold of all the program microphone channels is determined.

Because program microphone input channels **12** and **12'** are substantially identical, a detailed description of only channel **12** will be given, it being understood that corresponding reference numerals primed designate equivalent elements in channel **12'**.

Microphone channel **12** includes a preamplifier **16** to the input of which a microphone **18** is connected. Preamplifier **16** is of conventional design and in a typical system is a preamplifier including feedback gain adjustment and a switchable 150Hz high pass filter with a slope of 12 dB per octave. The audio output from preamplifier **16** is connected through a channel gain control attenuator **20** to the input of an audio signal controller **22**. Audio signal controller **22** includes a gate or control input terminal **24**, and can take the form of a variable attenuator, a variable gain amplifier, or a gate, its function being to produce an audio output signal that is proportional to the input at gate terminal **24**. The audio output of signal controller **22** is connected to a mixer and output controller **26** in which it is combined with other signals, e.g., that from signal controller **22'**.

A direct current signal proportional in level to the program material picked up by microphone **18** is compared to a corresponding signal produced by noise channel **14**, and for this purpose, program channel **12** includes, connected to the output of preamplifier **16**, an input high pass filter **28**, a logarithmic amplifier **30**, a full wave rectifier **32**, and a smoothing filter **34**, which is connected to one input **36***a* of a comparator **36**. Elements **28, 30, 32** and **34** cooperate to form a signal generator that produces at the input of comparator **36** a fluctuating DC voltage or direct current program envelope that has a level analogous to the logarithum of the amplitude envelope of the audio signal generated by microphone **18**. Comparator **36** has a second input **36***b*, and is arranged to produce at its output a gating signal only when the level of the signal at input **36***a* exceeds the level of the signal at input **36***b*. Input **36***b* is the non-inverting input of the comparator and to it is connected a DC signal having a magnitude proportional to the noise level in the environment in which the system is operative.

High-pass filter **28** reduces the effect of low-frequency signals on the control voltage, since acoustical standing waves at low frequencies will tend to mask directional information carried by the mid and high frequencies. It is typically a simple capacitive rolloff, down 3 dB at 300 Hz and decreasing at a rate of 6 dB octave. Logarithmic amplifier **30** compresses the voltage range of the audio signal to simplify subsequent processing. Its output is full-wave rectified at **32** and averaged by filter **34**, which typically has a time consultant of 7 milliseconds. Comparator **36** can be satisfactorily embodied in a high-gain DC amplifier with differential inputs and an output that swings between two levels according to which of the inputs is greater.

For producing a DC signal having a magnitude proportional to the ambient noise, a noise microphone **38** supplies the input for noise channel **14**. Noise channel **14** is substantially identical to the portion of program channel **12** by which a DC signal is generated that has the magnitude proportional to the magnitude of the audio program signal. More specifically, noise channel **14** includes a preamplifier **40** that is substantially identical to preamplifier **16**, a high pass filter **42** that is substantially identical to filter **28**, a logarithmic amplifier **44** that is substantially identical to amplifier **30**, a full wave rectifier **46** that is substantially identical to rectifier **32**, and a smoothing filter **48** that is substantially identical to filter **34**. The output of smoothing filter **48** is connected to a buffer amplifier **50** which supplies to a conductor **52** a DC signal that varies in magnitude in accordance with the level of noise sensed by microphone **38**. Conductor **52** is connected to input terminal **36***b* through a threshold control **54** and is similarly connected to the input **36***b'* of comparator **36'** through a threshold control **54'**. Conductor **52** is likewise connected to all other program channels to the end that the audio output of each microphone **18** is transmitted only if the program material impinging on the microphone exceeds by an appropriate amount the level of ambient noise. Threshold control 54 affords adjustment with respect to each program channel of the level at which comparator 36 will activate signal controller 22 to transmit the audio material through the program channel.

Between the output of comparator 36 and input 36*b* is a resistor 56 which provides positive feedback and thus affords hysteresis. Hysteresis is essential at this stage due to the inevitable inconsistencies in acoustically originated signals; in this context, the presence of hysteresis provides a difference in the level of the signal supplied to input 36*a* that will activate comparator 36 and the level of the signal at input 36*a* that will deactivate the comparator. A typical difference in the level to turn the comparator on and the level to turn the comparator off is 6 dB. It is essential that the amount of hysteresis be the same for both large and small signals, and this requirement is satisfied in the present invention because of the effect of logarithmic amplifiers 30 and 44 in the DC signal generators. The output of comparator 36 is connected through a non-linear filter 58 to control terminal 24 of signal controller 22. Filter 58 functions to condition the output signal of comparator 36 to a proper value to control whatever specific circuitry is employed in signal controller 22. Non-linear filter 38 typically includes a series diode and a parallel capacitor and functions to limit the voltage swing between one polarity and zero, and to delay the reaction time of signal controller 22 with respect to the occurrence of a gating signal from comparator 36. More particularly, it is desirable to slow the turn-on time slightly, e.g., 5 milliseconds, to prevent the generation of an audible switching transient, and to slow the turn-off of signal controller 22 for about 100 milliseconds to fade out the audio signal gradually rather than abruptly, a more desirable condition from the listener's standpoint. For providing a visual indication when comparator 36 applies an "on" signal to control terminal 24 of signal controller 22, a visual indicator 60 is connected in parallel with the control terminal. Visual indicator 60 can be a light producing device, such as a light emitting diode or an incandescent lamp, and assists the operator in adjusting each threshold control 54, 54′ during the installation and/or service of the system.

Program channel 12 has two outputs. The first is an audio output from signal controller 22 at conductor 62 which transmits the program material picked up by microphone 18 when the level of such signal is at a sufficiently high level to cause signal controller 22 to transmit the audio signal there-through. The second output of program channel 12 is a DC gating signal at conductor 64 which swings between two voltage levels, one indicating that the audio program material is at a lower level than the noise and the other indicating that the audio program material level exceeds the noise. The audio signals from each program channel are connected to output controller 26 where they are summed in a mixing network 66 which has an input for each of the respective conductors 62, 62′, etc. of the program channels 12, 12′, etc. The output of mixing or summing network 66 is connected through an amplifier 68 to the input of a variable gain amplifier 70. Variable gain amplifier 70 includes a control terminal 72; the amplifier is arranged to amplify the signals supplied thereto by an amount proportional to the magnitude of a control signal supplied to control terminal 72. The audio signal is thence connected through a final amplifier 74 to a loudspeaker system schematically identified at 76.

The gain or variable gain amplifier 70 is controlled in accordance with the number of microphones 18 that are transmitting audio signals to network 66 so as to prevent self oscillation or feed-back from occurring. For generating a signal for application to control terminal 72 to achieve this mode of operation an output control signal generator 78 is provided. Conductors 64, 64′, etc. are connected to an input summing resistor network 80 which constitutes the input of generator 78. The summed signal is amplified by amplifier 82 which drives a DC function generator 84, a conventional curve shaping circuit. The input to DC function generator 84 is a DC signal that has a discrete level that is dependent upon the number of program microphones 18 that are made active through the respective program channels 12 so that the output of amplifier 82 is analogous to the number of program input channels active at any time. The function generator is configured to produce an output appropriate for driving the variable gain amplifier 70 in whatever form it is actually embodied. Amplifier 70 and function generator 84 are adapted so that the overall electro-acoustical system power gain is constant irrespective of the number of program channels that are active. The desired condition is expressed by the formula:

$$E_{out} = E_{in} \sqrt{n/N}$$

or

$$\text{gain} = E_{out}/E_{in} = \sqrt{n/N}$$

in which E_{out} is the output voltage at the output of amplifier 70, E_{in} is the input voltage to amplifier 70, n is the number of microphones in the entire system and N is the number of microphones or program channels that are active at a given time. Function generator 84 includes a boost control, identified schematically at 86, which is arranged when set at a minimum to assure that the gain of amplifier 70 remains constant at a minimum value without being affected by the number of channels that are active. When boost control 86 is at a maximum, the gain adjusting function afforded by function generator 84 is fully effective. Boost control 86 is adjusted when the system is installed and when the nature of the program material supplied to the system is changed in order that feedback is avoided while maximum overall gain is achieved.

One system designed according to the present invention has six microphones 18 and six associated program channels 12. In such system the coaction of function generator 84 and variable gain amplifier 70 can be appreciated from the following table:

Number of Microphones 18 Activated	Boost in dB by Amplifier 70	Gain of Amplifier 70
1	+ 7.8	2.45
2	+ 4.8	1.73
3	+ 3.0	1.41
4	+ 1.8	1.23
5	+ 0.8	1.10
6	+ 0.0	1.00

The operation of the present invention is as follows: The microphones 18 are installed at appropriate locations in the area wherein sound reinforcement is desired, and conventional cables are employed to connect the microphones to the apparatus that houses program channels 12, 12′, etc., noise channel 14, controller 26, and signal generator 78. Noise microphone 38 is similarly connected to the apparatus. Noise microphone **38** is located at a suitable site so that the noise picked up thereby is typical or exemplary of the background noise impinging on the program microphones **18.** Each individual channel is then adjusted by manipulating threshold control **54** so that visual indicator **60** turns on when the desired program material is picked up by microphone **18** and turns off at all other times. This adjustment is repeated for each channel, e.g., **12'**. After all the individual channels are adjusted, boost control **86** is adjusted so that the overall system gain will be such as to avoid self-oscillation or feedback irrespective of the number of program channels that are active.

With the system adjusted as set forth above, and in the absence of any program input to microphones **18, 18'**, etc., all comparators **36, 36'**, etc. will be off because the ambient noise picked up by microphone **38** will cause input **36*b*** of the comparator to exceed that at input **36*a***. This condition of comparator **36** conditions signal controller **22** to block transmission of signal to conductor **62.** When an audio signal, e.g., voice, is directed toward a microphone, for example, microphone **18,** the DC signal which is developed by the generator composed of elements **28, 30, 32,** and **34** imposes a signal on input **36*a*** of the comparator that is greater than the noise level at input **36*b***, whereupon the comparator will produce a gate signal which is applied to control terminal **24** so as to cause signal controller **22** to transmit the audio signal to conductor **62** and output controller **26.** The amount of amplification or gain to which the audio signal is subjected is determined by the signal applied to control terminal **72** of variable gain amplifier **70** which in turn is determined by the number of program channels that are active at a given time. Thus, the output of amplifier **82** is proportional to the number of active program channels and this voltage level is converted by function generator **84** to a signal that is of suitable magnitude and polarity to effect the desired degree of control of variable gain amplifier **70.** For example, if one program channel is active, the gain of amplifier **70** will be relatively high and the material transmitted by such channel will be clearly heard by the audience. If, on the other hand, several program channels are active the audience will hear approximately the same overall power, but each individual voice, instrument, or like source, will be at a somewhat lower level. Accordingly, irrespective of the number of microphone channels that are active, there will be insufficient output power to cause feedback or self oscillation of the system.

Should self oscillation or feedback occur, the resultant noise produced thereby will impinge equally on noise microphone **38** and program microphones **18, 18'**, etc. Consequently, each comparator **36** will receive a noise input at terminal **36*b*** that causes the comparator to turn off the associated signal controller **22.** The system thus affords self suppression of feedback because loudspeaker **76,** noise microphone **38** and program microphones **18, 18'**, etc. reside in a common environment.

It is to be understood that the embodiment described herein is merely illustrative of the principles of the invention. For certain applications it will be advantageous to embody the invention in a form in which a noise microphone is provided for the control of each program microphone, and in others it will be possible to derive the ambient noise reference signal from the sum of all program microphone signals. Various modifications may be effected by persons skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. Sound reinforcement apparatus for a system that includes a plurality of program microphones and at least one loudspeaker and is adapted to operate in the presence of ambient noise, comprising in combination:

means for generating a direct current noise reference signal having a level proportional to the ambient noise level;

a plurality of audio signal processors, each of said processors being associated with a respective one of said program microphones, each said processor being adapted to transmit the output of the associated program microphone only when such output exceeds the ambient noise level and including

means for generating a direct current program envelope signal having a level proportional to the level of the associated program microphone output;

means for comparing said program envelope signal with the noise reference signal to develop a gating signal only when said program envelope signal exceeds the noise reference signal by a predetermined ratio;

an audio signal controller responsive to said gating signal for transmitting the audio output of the associated program microphone only when said gating signal is present; and

feedback means for providing hysteresis to maintain said gating signal so long as the audio output of the associated program microphone remains within a given increment of said predetermined ratio; and means for mixing outputs of all said processors and feeding them to said loud speaker.

2. Apparatus according to claim **1** wherein said output mixing means includes a summing network having an individual input associated with and connected to each respective audio signal controller, said network having a single output, a variable gain amplifier having an input connected to said single output, and means for varying the gain of said variable gain amplifier in proportion to the number of audio signal controllers that are transmitting.

3. Apparatus according to claim **2** wherein said gain varying means includes means for adding the DC output signals from all said comparing means in said processors to derive a DC voltage having a magnitude proportional to the number of said signal controllers that are transmitting, and means connecting said adding means to said variable gain amplifier so that said variable gain amplifier has a gain directly proportional to the quantity $\sqrt{n/N}$ in which n represents the total number of program microphones in the system and N represents the number of program microphones that are transmitting.

4. Apparatus according to claim **1** wherein said noise reference signal generating means comprises a noise microphone disposed in the same environment as said program microphones and said loudspeaker, means for rectifying the output of said noise microphone, and filter means connected to said rectifying means for generating a DC signal that varies as the envelope of the ambient noise impinging on said noise microphone, said rectifying means being connected to said comparing means in all said audio signal processors.

5. Apparatus according to claim 4 in combination with a logarithmic amplifier connected in circuit between said noise microphone and said rectifying means, said logarithmic amplifier being adapted to amplify low level noise signals by an amount greater than high level noise signals so as to compress the voltage range over which the ambient noise signal varies.

6. Apparatus according to claim 1 wherein said direct current program envelope generating means in each said audio signal processor comprises a logarithmic amplifier connected to the output of each said program microphone, said logarithmic amplifier being adapted to amplify low level program signals by an amount greater than high level program signals so as to compress the voltage range over which the audio signal varies, means for rectifying the output of said logarithmic amplifier, and filter means connected to said rectifying means for generating a DC signal that varies as the envelope of the audio program signal, said rectifying means being connected to said comparing means.

7. Apparatus according to claim 1 in combination with means connected to said comparing means for affording a visual indication when said gating signal is developed and means for selectively adjusting the predetermined ratio between said program envelope signal and said noise reference signal.

8. Apparatus according to claim 7 wherein said adjusting means includes a variable attenuator in circuit between said noise reference signal generating means and said comparing means.

9. Output control apparatus for an audio reinforcement system that has a plurality of audio program inputs and a single output, said control apparatus comprising a variable gain amplifier having an output terminal connected to said single output, an input terminal, and a control terminal, said variable gain amplifier being adapted to boost a signal applied at said input terminal by an amount proportional to the magnitude of a control signal applied to said control terminal, means for summing all said audio program inputs into said input terminal, and means connected to said control terminal for producing said control signal that automatically and continuously varies in proportion to the number of audio program inputs that are active so that the gain of said variable gain amplifier bears an inverse relation to the number of active audio program inputs.

10. Apparatus according to claim 9 in combination with means for generating a DC noise reference signal having a level proportional to the noise level in the audio program environment, means associated with each of said audio program inputs for generating a DC program envelope signal having a level proportional to the level of said audio program input, a plurality of comparators one of which is associated with each said audio program input and is adapted to produce a gating signal when the level of the program envelope signal exceeds the noise reference signal by a predetermined ratio, a network for adding all said gating signals, and means connecting said adding means to said variable gain amplifier so that said variable gain amplifier has a gain directly proportional to the quantity $\sqrt{n/N}$ in which n represents the total number of audio program inputs in the system and N represents the number of gating signals present.

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