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(54) **Loudspeaker line examination system**

(57) An audio signal from an audio signal source 2 is amplified in an amplifier 4, and the amplified audio signal is supplied through a loudspeaker line 6 to a plurality of loudspeakers 8 connected in parallel with each other. A test signal from a DSP 10 containing one or both of a frequency near the lowest frequency of the human audio frequency band and a frequency near the highest frequency, is combined with the audio signal in a combiner 13 and supplied to the loudspeaker line 6. Output signals of a current detecting circuit 14 and a voltage detecting circuit 16 disposed in the output of the amplifier 4 are supplied to a DSP 10 to analyze frequency components of the test signal, and a composite impedance of the loudspeakers 8 and the loudspeaker line 6 is computed based on the frequency component analysis. The DSP 10 compares the composite impedance with a threshold value to detect line breakage or decrease in impedance of the loudspeaker line.

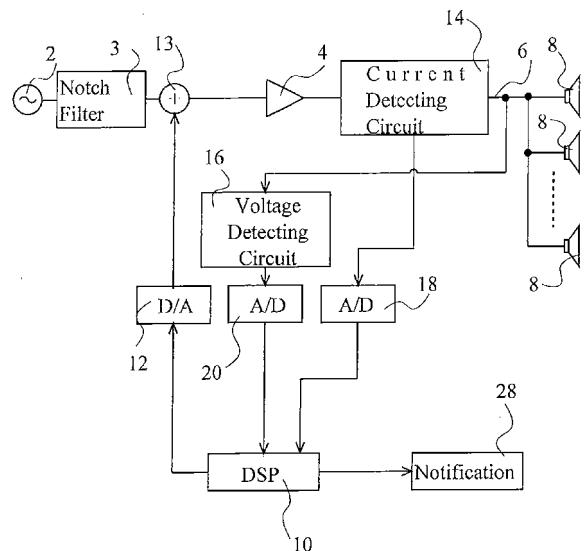


Fig.1

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Description

[0001] This invention relates to a loudspeaker line examination system for examining whether there are any problems such as line breakage or short-circuiting in loudspeaker lines in a public address system built in a building or the like.

[0002] An example of prior examination systems of the above-described type is disclosed in Patent Literature 1. In a public address system according to Patent Literature 1, a plurality of loudspeakers are connected to a loudspeaker line in parallel with each other, and a power amplifier is connected to the loudspeaker line. An audio signal and a test signal are combined in a stage preceding a power amplifier, and the power amplifier amplifies the resultant composite signal and applies it to the loudspeaker line. The test signal is a signal at a constant voltage. A detecting circuit is disposed in the output of the power amplifier, which includes a filter deriving test signal current flowing to respective loudspeakers through the loudspeaker line. Since the voltage of the test signal is constant, an output signal of the filter represents a composite impedance of the loudspeaker line and the respective loudspeakers. In the loudspeaker line examination system disclosed in Patent Literature 1, the value of the output signal of the filter is compared with a threshold value for use in detecting line breakage and a threshold value for use in detecting short-circuiting, to judge whether line breakage or short-circuiting has occurred. The examination system uses, as a reference value, the value of the filter output signal developed when the loudspeaker line operates properly, and uses a value resulting from adding a first predetermined value to the reference value as the line breakage detection threshold value, and a value resulting from subtracting a second predetermined value from the reference value as the short-circuiting detection threshold value.

Patent Literature 1: JP 2007-37024 A

[0003] As described, the background art examination system determines the two threshold values, using the value of the output signal of the filter developed when the loudspeaker line is in the proper operating state, and, therefore, in order to detect line breakage and short-circuiting with high accuracy, these threshold values must be set accurately. However, sometimes there is a large difference between the output signal value measured by the described examination system for determination of the threshold values, and the output signal value measured thereafter in the normal operating state in which there is no loudspeaker line breakage or short-circuiting occurred. For example, there may be a difference between the output signal value measured when only the test signal is supplied to the loudspeaker line, and the output signal value measured in the normal use of the public address system in which the audio signal at various frequencies and the test signal are supplied to the loudspeaker. The difference in value is significant when the level of the audio signal is larger than the level of the test signal. Accordingly, the examination system of the background art may make an erroneous judgment as if there were line breakage or short-circuiting, while the loudspeaker line is in the proper operating conditions, which erroneous judgment is caused by accurate setting of the first and second values.

[0004] An object of the present invention, therefore, is to provide an examination system which can make accurate detection of line breakage or impedance decrease in a loudspeaker line, with such erroneous judgment minimized as much as possible.

[0005] An examination system according to one embodiment of the invention is installed in a public address system. The public address system includes a signal source providing an audio signal. The audio signal is amplified in an amplifier, and the amplified audio signal is supplied to a loudspeaker line. A plurality of loudspeakers are connected to the loudspeaker line in parallel with each other. The examination system includes a signal source providing a test signal having either one or both of a frequency near the lowest frequency and a frequency near the highest frequency in the audio frequency band (normally from 20 Hz to 20 KHz) of humans. The test signal may be an analog signal, or an analog signal resulting from converting a digital signal by a digital-to-analog converter. The test signal is combined with the audio signal in a combiner, and the resultant composite is supplied to the amplifier. Thus, the amplified audio and test signals are supplied to the respective loudspeakers through the loudspeaker line. Impedance determining means derives the test signal component contained in the output signal of the amplifier and determines the impedance viewed from the output of the amplifier toward the respective loudspeakers, based on the derived test signal component. For example, the impedance determining means can determine one or more impedances by deriving a voltage and current of the test signal contained in the amplifier output. Alternatively, the impedance determining means may perform frequency analysis of the amplifier output as described later, to derive a frequency component of the test signal, to thereby determine one or more impedances corresponding to the frequency of the test signal. Judging means compares the impedance determined by the impedance determining means with a predetermined threshold value and judges the presence of at least one of line breakage and impedance decrease in the loudspeaker line. For example, when the line breakage detection threshold value is used, it is judged that line breakage of the loudspeaker line or inadequate connection of some loudspeaker has occurred if the measured impedance is larger than the line breakage threshold value. When the impedance decrease detection threshold value is used, it is judged that impedance decrease has occurred in the loudspeaker line if the determined impedance is lower than the impedance decrease detection threshold value. It can be arranged that both the line breakage detection threshold value and the impedance decrease detection threshold value may be prepared

so as to enable judgment of both. When the ratio of the resultant composite signal to the test signal is larger than a predetermined value, and the resultant composite signal is increasing, threshold revising means revises the threshold value in the direction to lower the degree of accuracy of judgment made in the judging means. The threshold value is set based on the impedance measured, while only the test signal is being supplied from the amplifier to the loudspeaker line.

[0006] The ratio of the composite signal to the test signal being large means that the proportion of the audio signal in the composite signal is large, and that the impedances of the loudspeaker line and the loudspeakers are under the influence of the audio signal. Therefore, erroneous judgment may result if the current threshold value is used, which is the reason why the threshold value is revised.

[0007] When the tendency of the composite signal to increase changes to the tendency to decrease, the threshold revising means may raise the degree of judgment accuracy which was lowered when the composite signal was increasing. In this case, the rate of change in the direction to lower the judgment accuracy is larger, and the rate of change in the direction to raise the judgment accuracy is smaller.

[0008] When the impedance of the loudspeaker line and the loudspeakers changes due to, for example, increase of the level of the audio signal, some time period may be necessary for the impedance to return to the original level from the level to which they changed, even when the level of the audio signal decreases. In order to cope with such situation, a smaller rate of change in the direction to raise the degree of judgment accuracy is employed.

[0009] A loudspeaker line examination system according to another embodiment of the invention is also installed in a public address system of the same arrangement as the one described with reference to the previous embodiment. The examination system includes a test signal source, too, but the test signal contains both frequencies near the lowest and highest frequencies of the human audio frequency band. The test signal is combined with the audio signal in a combiner, and the resultant composite signal is supplied to the amplifier. The impedance determining means derives the two frequency components of the test signal contained in the output signal of the amplifier, and determines, based on the derived frequency components, the impedance viewed from the output of the amplifier toward the loudspeakers. This impedance determining means is similar to the impedance determining means described with respect to the previous embodiment. Judging means compares the determined impedance with a predetermined threshold value and judges that the loudspeaker line and the loudspeakers have been open-circuited and/or that the impedance has decreased.

[0010] Since the test signal contains different frequency components, and the impedances are determined based on these two frequency components, with these impedances being compared with the threshold value, it is possible to judge, with a higher degree of accuracy, at least one of open-circuiting of the loudspeaker line and the loudspeakers and impedance decrease.

[0011] In the above-described two embodiments, the impedance determining means may determine the impedance in a time period during which the audio signal source stops operating. In such case, threshold setting means sets the threshold value based on the determined impedance. Second judging means judges whether the determined impedance is within a predetermined allowable range.

[0012] The impedances of the loudspeaker line and loudspeakers change with time. Accordingly, if the threshold value set on the basis of the impedances of the loudspeaker line and loudspeakers determined at a certain time is continuously used, a difference may be arisen between the actual impedances of the loudspeaker line and loudspeakers and the impedance of the loudspeaker line and loudspeakers determined for use in determining the threshold value. Therefore the impedance of the loudspeaker line and loudspeakers is determined during a time period during which no audio signal is supplied, and the threshold value is set on the basis of the thus determined impedance, in order to avoid erroneous judgment. Furthermore, by using the second judging means to judge whether the thus determined impedance Z is within the allowable range or not, it is possible to know when the loudspeakers should be replaced.

[0013] In the above-described two embodiments, the impedance determining means may include current detecting mean for detecting current flowing through the loudspeaker line, and voltage detecting means for detecting a voltage applied to the loudspeaker line. In such case, frequency component detecting means detects the frequency components of the test signal contained in the detected current and in the detected voltage. The detection of the frequency components may be done by the cross-spectrum analysis of the detected current and voltage, for example. Operating means computes the impedance from the detected test signal frequency components.

[0014] Since the impedance of the loudspeaker line and loudspeakers is measured based on the test signal components as described above, the impedance of the loudspeaker line and loudspeakers can be measured without being affected by the audio signal.

FIGURE 1 is a block diagram of a public address system with a loudspeaker examination system according to a first embodiment of the invention.

FIGURE 2 is a flow chart of frequency analyzing processing performed by a DSP of the examination system of FIGURE 1.

FIGURE 3 is a flow chart of root-mean-square value measuring processing performed by the DSP of the examination

system of FIGURE 1.

FIGURE 4 is a flow chart of short-circuiting, line breakage and impedance increase judging processing performed by the DSP of the examination system of FIGURE 1.

FIGURE 5 is a flow chart of threshold revising processing performed by the DSP of the examination system of FIGURE 1.

FIGURE 6 is a detailed flow chart of Zopen and Zinc revising processing in the threshold revising processing of FIGURE 5.

FIGURE 7 is an illustration of change a degree of measurement accuracy Ra as revised according to the processing of FIGURE 6.

FIGURE 8 is a detailed flow chart of Z1open and Z1inc computation in the Zopen and Zinc revising processing of FIGURE 6.

FIGURE 9 is a flow chart of aging judging processing performed by the DSP of the examination system of FIGURE 1.

[0015] An examination system according to one embodiment of the present invention is embodied in a public address system like the one shown in FIGURE 1. The public address system is a system for announcing in various places in, for example, a large-scale store. The public address system includes a signal source 2 providing an audio signal. The signal source 2 may be, for example, a sound source for providing background music over the store, or a microphone through which information about the store and emergency announcement is given. The audio signal from the signal source 2 is applied through a notch filter 3 to an amplifier, e.g. a power amplifier 4, where the audio signal is amplified, and applied to a plurality of loudspeakers 8 through a loudspeaker line 6 connected to the output of the power amplifier 4. The notch filter 3 is used to attenuate those frequency components of the audio signal which are the same as frequency components of a later-described test signal for the purpose of avoiding interference with the test signal. Accordingly, a circuit arrangement may be employed in which the audio signal is inputted to the amplifier through the notch filter 3 only when the test signal is being outputted, and is inputted to the amplifier without passing through the notch filter 3 while the test signal is not being outputted. In place of the notch filter 3, a low-pass filter and/or a high-pass filter may be used. The loudspeakers are disposed at various locations in the store. In FIGURE 1, although only one loudspeaker line 6 is shown, the loudspeaker line 6 is actually composed of a pair of lines. The loudspeakers 8 are actually connected between the pair of loudspeaker lines 6 in parallel with each other.

[0016] The examination system includes a DSP (digital signal processor) 10 functioning as a signal source of the test signal at an inaudible frequency. The DSP 10 provides a digital test signal as the test signal. The digital test signal is converted to an analog test signal in a D/A (digital-to-analog) converter 12. The analog test signal and the audio signal from the signal source 2 are combined in a combiner 13. The resultant composite signal from the combiner 13 is applied to the power amplifier 4. The analog test signal is a signal containing two frequency components at, for example, 40 Hz and 20 KHz, and has a constant voltage value. Generally, the human audio frequency band is from 20 Hz to 20 KHz. The loudspeakers 8 are so designed as to give optimum sound in this human audio frequency band. The test signal is used for the purpose of measuring a composite impedance of the loudspeaker line and loudspeakers 8 connected in parallel to the loudspeaker line. Accordingly, although the frequency of the test signal desirably is within the audio frequency band, it is not desirable for the test signal components in the resultant signal, which results from combining the test signal with the audio signal, to be delivered as noise to human ears. Then, it is desirable to use, as the frequency of the test signal, either one or both of a frequency near the lowest frequency or a frequency near the highest frequency within the audio frequency band which is or are hard for human ears to sense. The loudspeakers 8 are supplied with the audio signal and the test signal as amplified in the power amplifier 4. The test signal is continuously supplied to the combiner 13 from the D/A converter 12. The audio signal is not supplied to the combiner 13 when it is not required. Alternatively, the audio signal from the signal source 2 may be A/D (analog-to-digital) converted before being combined with the test signal. In such case, the resultant composite signal is applied to the D/A converter 12.

[0017] A current detecting circuit 14 is connected in series in the output of the power amplifier 4. The current detecting circuit 14 detects the output current supplied from the power amplifier 4 to the loudspeaker line 6. Also, a voltage detecting circuit 16 is disposed in parallel in the output of the power amplifier 4. The voltage detecting circuit 16 detects the output voltage applied from the power amplifier 4 to the loudspeaker line 6.

[0018] The output signal of the current detecting circuit 14 and the output signal of the voltage detecting circuit 16 are digitized in A/D converters 18 and 20, respectively, before being applied to the DSP 10. Hereinafter, the digitized version of the output signal of the current detecting circuit 14 is referred to as a digital current detection signal, and the digitized version of the output signal of the voltage detecting circuit 16 is referred to as a digital voltage detection signal.

[0019] The DSP 10 processes the digital current detection signal, the digital voltage detection signal and the digital test signal, and judges whether the respective loudspeakers 8 and the loudspeaker line 6 are broken or short-circuited, or whether the impedance of the loudspeakers 8 and the loudspeaker line 6 have significantly decreased. The result of judgment is notified by a notification device 28. The notification device may be, for example, a display device, on which the result of judgment is displayed.

[0020] In the DSP 10, each time the successively supplied digital current detection and digital voltage detection signals are inputted to the DSP 10, the frequency analyzing processing shown in FIGURE 2 is performed.

[0021] In the frequency analyzing processing, noise frequency components are first removed from the digital current detection and digital voltage detection signals in a band-pass filter (Step S2). Then, the digital current detection and digital voltage detection signals from which noise frequency components have been removed are averaged (Step S4). Specifically, the DSP 10 is provided therein with memories equal in number to the digital current detection and digital voltage detection signals in one cycle of the test signal, and each time the digital current detection and digital voltage detection signals are supplied to the DSP 10 from the band-pass filter, they are stored in the corresponding memories over a plurality of cycles. The stored values in the memories are divided by the number of the plural cycles. The thus averaged digital current detection and digital voltage detection signals are subjected to cross-spectrum analysis to determine the correlation between the test signals contained in the digital current detection and digital voltage detection signals, and an impedance Z1 at the frequency of 20 KHz, an impedance Z2 at the frequency of 40 Hz, and the coherence of the digital current detection and digital voltage detection signals in the test signal are computed (Step S6). It should be noted that when the DSP 10 has high processing ability, Steps S2 and S4 may be skipped, and only the cross-spectrum analysis in Step S6 is sufficient.

[0022] If it is determined from the coherence that there are many frequency components other than the test signal frequency components, the DSP 10 raises the voltage of the constant-voltage test signal.

[0023] Subsequent to the processing shown in FIGURE 2, the root-mean-square values V_{rms} and I_{rms} of the digital voltage detection and digital current detection signals are computed as shown in FIGURE 3 (Step S8).

[0024] Next, as shown in FIGURE 4, using the impedances Z1 and Z2 obtained by the above-described cross-spectrum analysis and the root-mean-square value I_{rms} of the digital current detection signal, judgment is made as to whether any one of short-circuiting, decrease in impedance (increase of output current of the power amplifier 4) and open-circuiting has occurred in the loudspeaker line 6 and the loudspeakers 8.

[0025] First, judgment is made as to whether the root-mean-square value I_{rms} of the digital current detection signal is larger than a predetermined threshold value, e.g. a short-circuiting current value I_{sl} of the loudspeaker line, or whether the measured impedance Z1 is smaller than a predetermined threshold value, e.g. a short-circuiting impedance $Z1_{sl}$ at 20 KHz of the loudspeaker line 6 and the loudspeakers 8, and, at the same time, the measured impedance Z2 is larger than a predetermined threshold value, e.g. a short-circuiting impedance $Z2_{sl}$ at 40 Hz of the loudspeaker line 6 and the loudspeakers 8 (Step S14). The short-circuiting current I_{sl} and the short-circuiting impedances $Z1_{sl}$ and $Z2_{sl}$ are predetermined in view of the protection of the loudspeaker line 6 and the loudspeakers 8. If the answer to the query in Step S14 is YES, from which it is judged that there is short-circuiting in the loudspeaker line 6 etc., such short-circuiting is indicated on the display device (Step S16), and this judgment processing is ended.

[0026] When the answer to the query in Step S14 is NO, judgment is made as to whether the measured impedance Z1 is smaller than the lower limit value $Z1_{inc}$ for 20 KHz or whether the impedance Z2 is smaller than the lower limit value $Z2_{inc}$ for 40 Hz (Step S18). The lower limit values $Z1_{inc}$ and $Z2_{inc}$ are explained later. When the answer to the query in Step S18 is YES, which means that, while the loudspeaker line current has not yet increased to the value indicating short-circuiting, the output current from the power amplifier 4 has increased to some extent and requires some caution, current increase is displayed (Step S20), and this judgment is ended.

[0027] If the answer to the query in Step S18 is NO, judgment is made as to whether the measured impedance Z1 is larger than the upper limit value $Z1_{open}$ for 20 KHz or whether the impedance Z2 is larger than the upper limit value $Z2_{open}$ for 40 Hz (Step S22). The upper limit values $Z1_{open}$ and $Z2_{open}$ are explained later. When the answer to the query in Step S22 is YES, from which it is judged that open-circuiting has happened in the loudspeaker line 6 and the loudspeakers 8, open-circuiting is displayed (Step S24), and this judgment is ended.

[0028] In making the above-described judgments, the upper limit values $Z1_{open}$ and $Z2_{open}$ and the lower limit values $Z1_{inc}$ and $Z2_{inc}$ are used. These values are determined, based on a reference impedance $Z1_{ave}$ at 20 KHz and a reference impedance $Z2_{ave}$ at 40 Hz of the loudspeaker line 6 and loudspeakers 8, respectively. The reference impedances $Z1_{ave}$ and $Z2_{ave}$ are set by a worker when the worker initializes the public address system on the first use after its installation, or are set by the worker when the public address system is re-initialized for some reason. Sometimes, however, it may happen that there are large differences between these reference impedances $Z1_{ave}$ and $Z2_{ave}$ and the impedances Z1 and Z2 measured afterwards in a normal condition where there is no line breakage or short-circuiting in the loudspeaker line 6 and loudspeakers 8. For example, if the impedances Z1 and Z2 are measured during the usual operation of the public address system, with an audio signal having various frequencies and the test signal being supplied to the loudspeaker line 6, there is a possibility that the measured impedance Z1 is different from the reference impedance $Z1_{ave}$ and the impedance Z2 is different from the reference impedance $Z2_{ave}$. The differences in value are significant particularly when the level of the audio signal is larger than that of the test signal. Then, as shown in FIGURE 5, after the above-described judgment is done, the upper limit values $Z1_{open}$ and $Z2_{open}$ and the lower limit values $Z1_{inc}$ and $Z2_{inc}$, which are prepared based on the reference impedances $Z1_{ave}$ and $Z2_{ave}$, are subjected to revising processing.

[0029] In the revising processing, judgment is first made as to whether the root-mean-square value V_{rms} of the digital

voltage detection signal is larger, by a predetermined factor, e.g. 1.2, or more, than the root-mean-square voltage value V_{test} of the digital test signal (Step S26). If the answer is YES, it is judged that many components at the same frequencies as the test signal are contained in the audio signal. Then, the computation processing for revising the upper limit values $Z1_{open}$ and $Z2_{open}$ and the lower limit values $Z1_{inc}$ and $Z2_{inc}$ is executed (Step S28). It should be noted that the predetermined factor is not limited to 1.2.

[0030] In the revising computation processing in Step S28, a degree of measurement accuracy R_a of the measured impedances $Z1$ and $Z2$ is used. The unit of the degree of measurement accuracy R_a is percent (%). The smaller the value, the degree of measurement accuracy of the impedance $Z1$, $Z2$ is higher, and the larger the value, the degree of measurement accuracy R_a of the impedance $Z1$, $Z2$ is lower. The degree of measurement accuracy R_a is set to the smallest value, for example, 5 %, when V_{rms} is equal to V_{test} . As shown in FIGURE 6, judgment is made, in the revision computation processing in Step S28, as to whether the digital voltage detection signal V_{rms} is larger than the digital voltage detection signal ΔV_{rms} used in the previous revision computation processing (Step S30). When the answer to the query made in Step S30 is YES, which means that audio signal components, except the test signal, at the same frequencies as the test signal, have increased from the previous revision computation processing, the value of the degree of measurement accuracy R_a must be revised to a great extent. For that purpose, computation,

$$R_a = \beta R_a + \alpha f(V_{rms}/V_{test}),$$

is carried out. In this equation, α and β are predetermined factors, and there are relationship between α and β , that $\alpha + \beta = 1$ and $\alpha > \beta$. The function $f(V_{rms}/V_{test})$ is a function with an argument V_{rms}/V_{test} , and its value increases when the value of V_{rms}/V_{test} is increasing and decreases when the value of V_{rms}/V_{test} is decreasing. Thus, since the value of V_{rms}/V_{test} is changing greatly and $\alpha > \beta$, the proportion of $\alpha f(V_{rms}/V_{test})$ in the revised degree of measurement accuracy R_a is large, and, the revised degree of measurement accuracy R_a increases rapidly when the value of V_{rms}/V_{test} is increasing, as shown in the first half portion of FIGURE 7.

[0031] When the answer to the query made in Step S30 is NO, which means that audio signal components at the same frequencies as the test signal, except the test signal, present when the previous revision was performed, have decreased, the degree of measurement accuracy R_a is revised to have a smaller value. The rate of change in the decreasing direction, however, is smaller. For that purpose, a computation,

$$R_a = \alpha R_a + \beta f(V_{rms}/V_{test})$$

is performed. Since the value of V_{rms}/V_{test} is smaller, $f(V_{rms}/V_{test})$ is also smaller. Since $f(V_{rms}/V_{test})$ is multiplied by β , which is smaller than α , the proportion of $\beta f(V_{rms}/V_{test})$ in the revised R_a is small, and the value of the revised R_a gradually decreases when the value of V_{rms}/V_{test} is decreasing, as is seen in the latter half portion of FIGURE 7.

[0032] Using the thus revised degree of measurement accuracy R_a , the computations of $Z1_{open}$, $Z2_{open}$, $Z1_{inc}$ and $Z2_{inc}$ are performed (Step S36). For use in the next execution of Step S30, V_{rms} is memorized as ΔV_{rms} (Step S38).

[0033] The computation of $Z1_{open}$ and $Z1_{inc}$ in Step S36 is done in the manner shown in FIGURE 8. First, judgment is made as to whether the degree of measurement accuracy R_a is larger than an impedance open-circuiting proportion initial value R_{ul} (Step S40). The impedance open-circuiting proportion initial value R_{ul} is expressed in percent (%), and is a proportion of the upper limit impedance to the reference impedance ($Z1_{ave}$, $Z2_{ave}$). The upper limit impedance is the impedance at which the loudspeaker line 6 etc. can be considered to have been open-circuited, with the degree of measurement accuracy R_a being highest, or, in other words, with R_a having the smallest value. The impedance open-circuiting proportion initial value R_{ul} is set by the worker at the time of initialization or re-initialization of the system, and is used for both $Z1_{open}$ and $Z2_{open}$. When the answer to the query made in Step S40 is NO, it is not necessary for the degree of measurement accuracy R_a to be increased above the impedance open-circuiting proportion initial value R_{ul} , and, therefore, $Z1_{open}$ is computed according to

$$Z1_{open} = Z1_{ave}(1 + R_{ul}/100)$$

(Step S42).

[0034] If the answer to the query made in Step S40 is YES, it is necessary to revise $Z1_{open}$ based on the degree of measurement accuracy R_a , and $Z1_{open}$ is computed (Step S44) according to

$$Z_{1open} = Z_{1ave}(1 + R_a/100).$$

5 **[0035]** Following Step S42 or S44, judgment is made as to whether Z_{1open} is larger than an upper limit value Z_{1ul} of the impedance at 20 KHz (Step S46). The upper limit impedance value Z_{1ul} is the upper limit value of the impedance expected to actually occur at 20 KHz when the loudspeaker line 6 etc. are open-circuited. The upper limit value Z_{1ul} is manually set by the worker at the time of initialization or re-initialization of the system. Alternatively, Z_{1ave} measured by DSP 10 at the time of initialization or re-initialization of the system is multiplied by a factor greater than 1, and the resultant product is set as the upper limit value Z_{1ul} . The reason why the judgment in Step S46 is done is that it is sometimes possible for the value of Z_{1open} revised based on the degree of measurement accuracy R_a to be an impossible value. When the answer to the query made in Step S46 is YES, Z_{1open} is used as Z_{1ul} (Step S48) since it is impossible that Z_{1open} is greater than Z_{1ul} .

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15 **[0036]** Subsequent to Step S48, or when the answer to the query made in Step S46 is NO, judgment is made as to whether the degree of measurement accuracy R_a is larger than an impedance increase proportion initial value R_{11} (Step S50). The impedance increase proportion initial value R_{11} is a value resulting from subtracting 1 (unity) from the reciprocal of the proportion of the reference impedance (Z_{1ave} or Z_{2ave}) to the impedance at which the impedance of the loudspeaker line 6 and the loudspeakers 8, when the degree of measurement accuracy R_a is highest, can be considered to have decreased. The impedance increase proportion initial value R_{11} is expressed in percent (%). The impedance increase proportion initial value R_{11} is set by the worker when the system is initialized or re-initialized, and is used for both of Z_{1inc} and Z_{2inc} . If the answer to the query in Step 50 is NO, Z_{1inc} is computed (Step S52) according to

$$Z_{1inc} = Z_{1ave}(1 + R_{11}/100)$$

25 since it is not necessary to decrease the degree of measurement accuracy R_a below R_{11} .

[0037] If the answer to the query made in Step S50 is YES, it is necessary to revise Z_{1inc} according to the degree of measurement accuracy R_a , and, therefore, Z_{1inc} is computed (Step S54) according to

$$Z_{1inc} = Z_{1ave}/(1 + R_a/100).$$

30
35 **[0038]** Subsequent to Step S52 or S54, judgment is made as to whether Z_{1inc} is smaller than a lower limit value Z_{1ll} of the impedance Z_1 at 20 KHz (Step S56). The impedance lower limit value Z_{1ll} is the lower limit value at 20 KHz at which impedance decrease is expected to actually occur while no short-circuiting has occurred in the loudspeaker line 6 or the loudspeakers 8. The lower limit value Z_{1ll} is manually set by the worker at the time of initialization or re-initialization of the system. Alternatively, the product of Z_{1ave} measured by the DSP 10 at the time of initialization or re-initialization of the system multiplied by a factor smaller than 1 (unity) is set as the lower limit value Z_{1ll} . Step S56 is executed since Z_{1inc} revised in Step S54 sometimes takes a value which it cannot actually take. If the answer to the query made in Step S56 is YES, Z_{1inc} is adopted as Z_{1ll} (Step S58) since it is impossible for Z_{1inc} to be smaller than Z_{1ll} . When the execution of Step S58 is finished or if the answer to the query made in Step S56 is NO, the processing for computing Z_{1open} and Z_{2open} is ended.

40
45 **[0039]** By the processing similar to the ones described above, Z_{2open} and Z_{2inc} are computed, using the impedance open-circuiting proportion initial value R_{ul} , the impedance increase proportion initial value R_{11} , an upper limit value Z_{2ul} of the impedance Z_2 at 40 Hz, a lower limit value Z_{2ll} of the impedance Z_2 at 40 Hz, and the reference impedance Z_{2ave} of the impedance Z_2 at 40 Hz. Description of this processing is not made.

50 **[0040]** Let it be assumed, for example, that Z_{2ave} is 1,000 Ω , Z_{2ul} is 2,000 Ω , Z_{2ll} is 500 Ω , Z_{2sl} is 20 Ω , Z_{1ave} is 1,500 Ω , Z_{1ul} is 3,000 Ω , Z_{1ll} is 750 Ω , Z_{1sl} is 30 Ω , I_{sl} is 5 A, R_{ul} is 10 %, R_{11} is 10 %, R_a is 5 %, and V_{test} is 5 V. The R_a of 5 % is the highest degree of accuracy. A state in which V_{rms} is 5 V is maintained, with the above-assumed values maintained, since $R_a < R_{ul}$, Z_{1open} and Z_{2open} are:

$$Z_{2open} = 1,000 \Omega \times (1 + 5/100) = 1,050 \Omega$$

$$Z_{1open} = 1,500 \Omega \times (1 + 5/100) = 1,575 \Omega$$

5 Also, since $R_a > R_{il}$, Z_{2inc} and Z_{1inc} are:

$$Z_{2inc} = 1,000 \Omega / (1 + 5/100) = 952 \Omega$$

10

$$Z_{1inc} = 1,500 \Omega / (1 + 5/100) = 1,428 \Omega$$

15 **[0041]** In this condition, if the measured impedance Z_2 is $1,000 \Omega$ and the measured impedance Z_1 is $1,500 \Omega$, it is judged by the processing shown in FIGURE 4 that the loudspeaker line is in the proper state. Similarly, if the measured impedances Z_2 and Z_1 are $1,100 \Omega$ and $1,500 \Omega$, respectively, it is judged by the processing shown in FIGURE 4 that open-circuiting is present. If the measured impedances Z_2 and Z_1 are $1,100 \Omega$ and $1,600 \Omega$, respectively, it is judged by the processing shown in FIGURE 4 that open-circuiting is present. If the measured impedances Z_2 and Z_1 are $1,000 \Omega$ and $1,400 \Omega$, respectively, it is judged by the processing shown in FIGURE 4 that increase has occurred. If the measured impedances Z_2 and Z_1 are 15Ω and 10Ω , respectively, it is judged by the processing shown in FIGURE 4 that short-circuiting has occurred.

20 **[0042]** Let it be assumed that a condition in which the audio signal contains components at the same frequencies as the test signal to some extent, in addition to the test signal, and V_{rms} is larger than V_{test} , for example, V_{rms} is 10 V , continues for some time, resulting in rapid increase of R_a to, for example, 50% , due to the processing shown in FIGURE 6. Since $R_a > R_{ul}$,

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$$Z_{2open} = 1,000 \Omega \times (1 + 50/100) = 1,500 \Omega$$

$$Z_{1open} = 1,500 \Omega \times (1 + 50/100) = 2,250 \Omega$$

35

Also, since $R_a > R_{il}$,

40

$$Z_{2inc} = 1,000 \Omega / (1 + 50/100) = 667 \Omega$$

$$Z_{1inc} = 1,500 \Omega / (1 + 50/100) = 1,000 \Omega$$

45

[0043] In this condition, if the measured impedance Z_2 is $1,100 \Omega$ and the measured impedance Z_1 is $1,600 \Omega$, it is judged by the processing shown in FIGURE 4 that the loudspeaker line is in the normal state. If the measured impedances Z_2 and Z_1 are $2,300 \Omega$ and $1,000 \Omega$, respectively, it is judged by the processing shown in FIGURE 4 that open-circuiting has occurred. If the measured impedances Z_2 and Z_1 are $1,400 \Omega$ and 600Ω , respectively, it is judged by the processing shown in FIGURE 4 that current has increased. If the measured impedances Z_2 and Z_1 are 15Ω and 10Ω , respectively, it is judged by the processing shown in FIGURE 4 that short-circuiting has occurred.

50 **[0044]** Let it be assumed that a condition in which the audio signal contains, in addition to the test signal, a large amount of components at the same frequencies as the test signal, and V_{rms} is significantly larger than V_{test} , for example, V_{rms} is 30 V , continues for some time, resulting in rapid increase of R_a to, for example, 300% , due to the processing shown in FIGURE 6. Since $R_a > R_{ul}$,

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$$Z_{2open} = 1,000 \Omega \times (1 + 300/100) = 4,000 \Omega$$

$$Z_{1open} = 1,500 \Omega \times (1 + 300/100) = 6,000 \Omega$$

5 However, since $Z_{2open} > Z_{2ul}$ and $Z_{1open} > Z_{1ul}$, Z_{2open} and Z_{1open} are changed to:

$$Z_{2open} = Z_{2ul} = 2,000 \Omega$$

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$$Z_{1open} = Z_{1ul} = 3,000 \Omega$$

Also, since $R_a > R_{II}$,

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$$Z_{2inc} = 1,000 \Omega / (1 + 300/100) = 250 \Omega$$

20

$$Z_{1inc} = 1,500 \Omega / (1 + 300/100) = 375 \Omega$$

Since $Z_{2inc} < Z_{2II}$ and $Z_{1inc} < Z_{1II}$, Z_{2inc} and Z_{1inc} are changed to:

25

$$Z_{2inc} = Z_{2II} = 500 \Omega$$

30

$$Z_{1inc} = Z_{1II} = 750 \Omega$$

35 **[0045]** In this condition, if the measured impedance Z_2 is $1,000 \Omega$ and the measured impedance Z_1 is $1,600 \Omega$, it is judged by the processing shown in FIGURE 4 that the loudspeaker line is normal. If the measured impedances Z_2 and Z_1 are $2,500 \Omega$ and $2,800 \Omega$, respectively, it is judged by the processing shown in FIGURE 4 that open-circuiting has occurred. If the measured impedances Z_2 and Z_1 are 400Ω and $1,000 \Omega$, respectively, it is judged by the processing shown in FIGURE 4 that current has increased. If the measured impedances Z_2 and Z_1 are 15Ω and 10Ω , respectively, it is judged by the processing shown in FIGURE 4 that short-circuiting has occurred.

40 **[0046]** Even if the state in which V_{rms} is 30 V returns to the state in which V_{rms} is 10 V , for example, R_a does not change to 50% , but only decreases slightly, due to the processing of Step S34 in FIGURE 6. Accordingly, Z_{2open} slightly decreases from $4,000 \Omega$, Z_{1open} slightly decreases from $6,000 \Omega$, Z_{2inc} slightly increases from 500Ω , and Z_{1inc} slightly increases from 750Ω . With this arrangement, if, for example, the loudspeakers 8 generate heat due to a large value of V_{rms} , and it takes a long time for the temperature of the loudspeakers 8 to return to the temperature before they began to generate heat, erroneous judgment can be avoided since it takes a long time for Z_{1open} , Z_{2open} , Z_{1inc} and Z_{2inc} to return to their values before the heat generation occurred.

45 **[0047]** In this examination system, the reference impedances Z_{1ave} and Z_{2ave} at 20 KHz and 40 Hz of the loudspeaker line 6 and the loudspeakers 8 are measured prior to the application of the audio signal, and judgment is made as to whether the reference impedance Z_{1ave} is between predetermined allowable aging upper and lower limit values Z_{1UL} and Z_{1LL} for 20 KHz , or whether the reference impedance Z_{2ave} is between predetermined allowable aging upper and lower limit values Z_{2UL} and Z_{2LL} for 40 Hz . Specifically, as the public address system is operated for a long time, the impedance of the loudspeakers 8 changes due to aging, and the reference impedances Z_{1ave} and Z_{2ave} also change as the impedance of the loudspeakers 8 changes. Judgment is made as to whether the reference impedance Z_{1ave} is within an allowable range defined by the allowable upper limit Z_{1UL} and the allowable lower limit Z_{1LL} , which are the limits for 20 KHz indicating the necessity for replacement of the loudspeakers, or whether the reference impedance Z_{2ave} is within an allowable range defined by the allowable upper limit Z_{2UL} and the allowable lower limit Z_{2LL} , which are the limits for 40 Hz indicating the necessity for replacement of the loudspeakers. If the reference impedance Z_{1ave}

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is outside the allowable range defined by the allowable upper limit Z1UL and the allowable lower limit Z1LL, or if the reference impedance Z2ave is outside the allowable range defined by the allowable upper limit Z2UL and the allowable lower limit Z2LL, an indication to recommend the replacement of loudspeakers is displayed on the notification device 28. Such judgment is made at a time when the public address system is not in use. For example, if the public address system is installed in a store, the judgment is made everyday at a given time within a time period after the store is closed and before the store is opened.

[0048] As shown in FIGURE 9, whether the time for examination comes or not is judged (Step S60). If the answer to the query made in Step S60 is NO, the processing is ended. If the answer is YES, the DSP 10 provides the test signal (Step S62). Then, the reference impedances Z1ave and Z2ave are measured in the manner described with reference to FIGURE 2 (Step S64). Judgment is made as to whether Z1ave is within the above-described allowable range defined by Z1UL and Z1LL and, at the same time, whether Z2ave is within the above-described allowable range defined by Z2UL and Z2LL (Step S66). If the answer to the query made in Step S66 is NO, an error notification is displayed on the notification device 28 (Step S68) to recommend replacement of a loudspeaker. If the answer is YES, the measured Z1ave and Z2ave are stored (Step S70). The execution of the processing of Step S70 renews Z1ave and Z2ave for use in computing Z1open, Z2open, Z1inc and Z2inc in the processing shown in FIGURE 8 in later stages. This prevents erroneous judgment which would be caused by influence given by changes in impedance caused by aging.

[0049] According to the described embodiment, cross-spectrum analysis is used to determine the impedances Z1, Z2, Z1ave and Z2ave, but the impedances may be determined by using a band-pass filter having a narrow band capable of deriving the test signal to derive current and voltage of the test signal, and determine the impedances from the derived current and voltage, for example. Also, according to the described embodiment, the test signal used has frequencies of 40 Hz and 20 KHz, but a test signal at either one of 40 Hz and 20 KHz, for example, may be used instead. Further, according to the described embodiment, the digital test signal from the DSP 10 is digital-to-analog converted and the resultant analog test signal is applied to the combiner 13. Instead, an analog test signal source is additionally used and a test signal from this analog test signal source may be applied to the combiner 13. In such case, the analog test signal is analog-to-digital converted and the resultant digital signal is applied to the DSP 10. According to the described embodiment, open-circuiting and decrease in impedance of the loudspeaker line and loudspeakers are determined, but only one of them may be determined, instead.

Claims

1. A loudspeaker line examination system in a public address system, said public address system comprising:

a signal source of an audio signal;
 an amplifier for amplifying said audio signal;
 a loudspeaker line through which an output signal of said amplifier is transmitted; and
 a plurality of loudspeakers connected in parallel with each other to said loudspeaker line;
 said loudspeaker line examination system comprising:

a signal source of a test signal containing two frequency components;
 a combiner for combining said test signal with said audio signal and applying a resultant signal to said amplifier;
 impedance determining means for deriving said two frequency components of said test signal contained in an output signal of said amplifier and determining, from the derived frequency components, an impedance viewed from the output of said amplifier toward said loudspeakers; and
 judging means for comparing the determined impedance with a predetermined threshold value to judge whether at least one of open-circuiting and decrease in impedance of said loudspeaker line and loudspeakers has occurred.

2. The loudspeaker line examination system according to Claim 1, wherein:

said impedance determining means determines said impedance in a time period during which said signal source of audio signal is not operating; and
 said loudspeaker line examination system further comprises:

threshold value setting means for setting said threshold value based on the determined impedance; and
 second judging means for judging whether said determined impedance is within a predetermined allowable range.

3. The loudspeaker line examination system according to Claim 1, wherein said impedance determining means comprises:

5 current detecting means for detecting current flowing through said loudspeaker line;

voltage detecting means for detecting a voltage applied to said loudspeaker line;

frequency component detecting means for detecting a frequency component of said test signal contained in the current as detected by said current detecting means and in the voltage as detected by said voltage detecting means; and

10 computing means for computing said impedance from the test signal frequency component in said detected current voltage.

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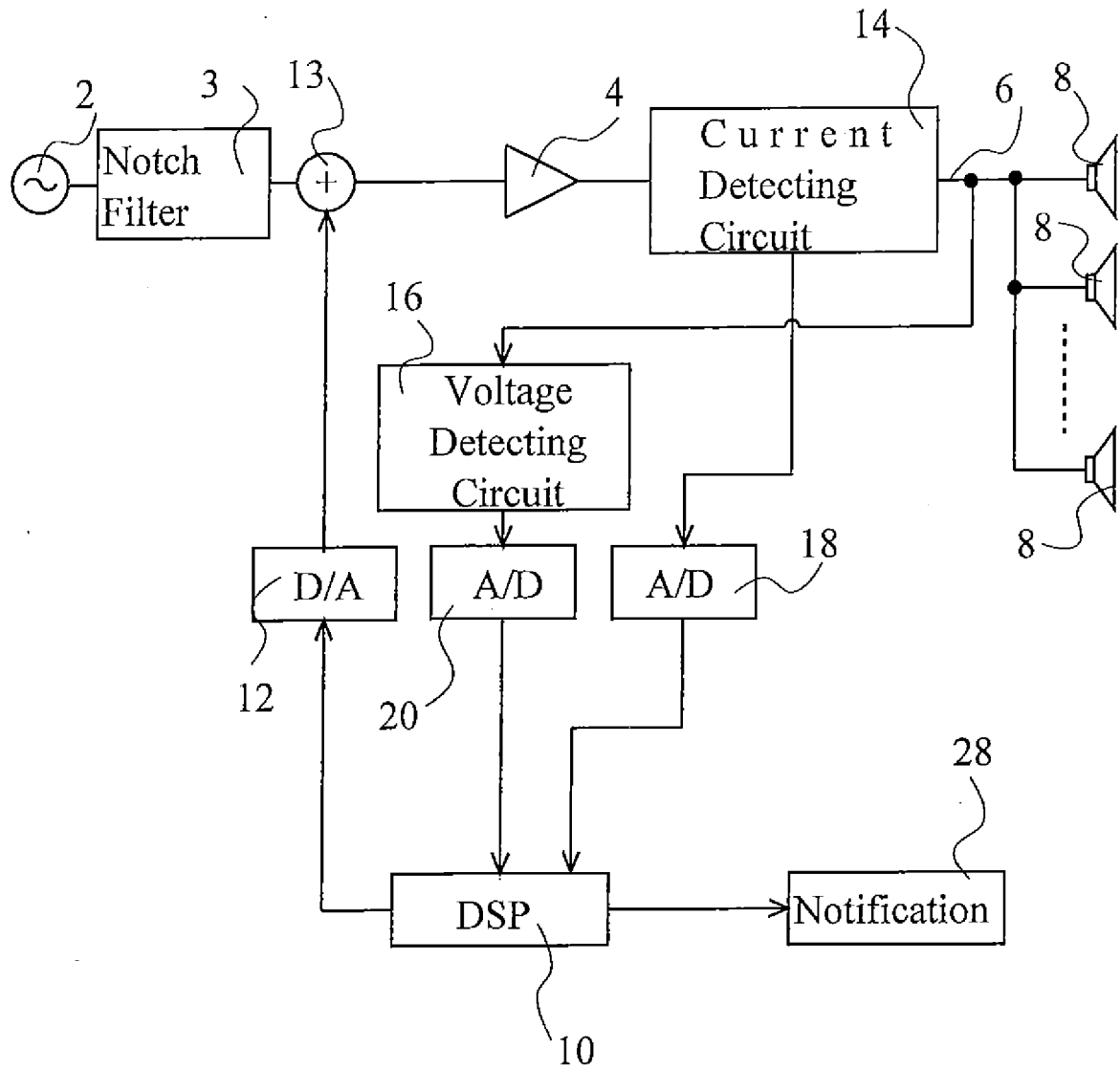


Fig.1

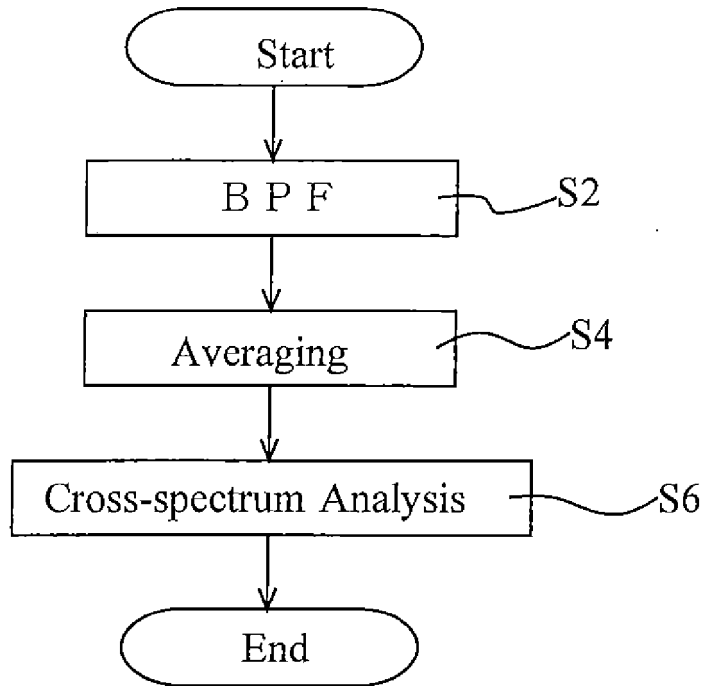


Fig.2

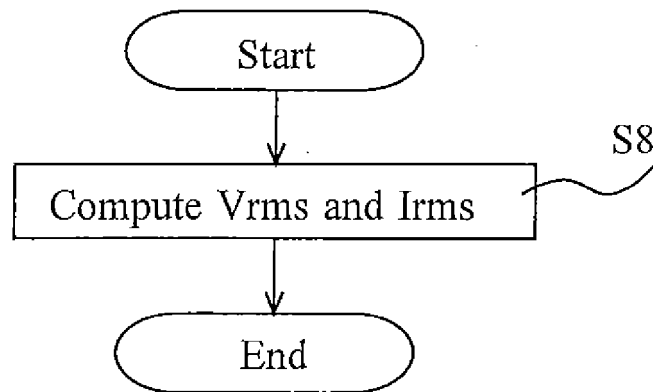


Fig.3

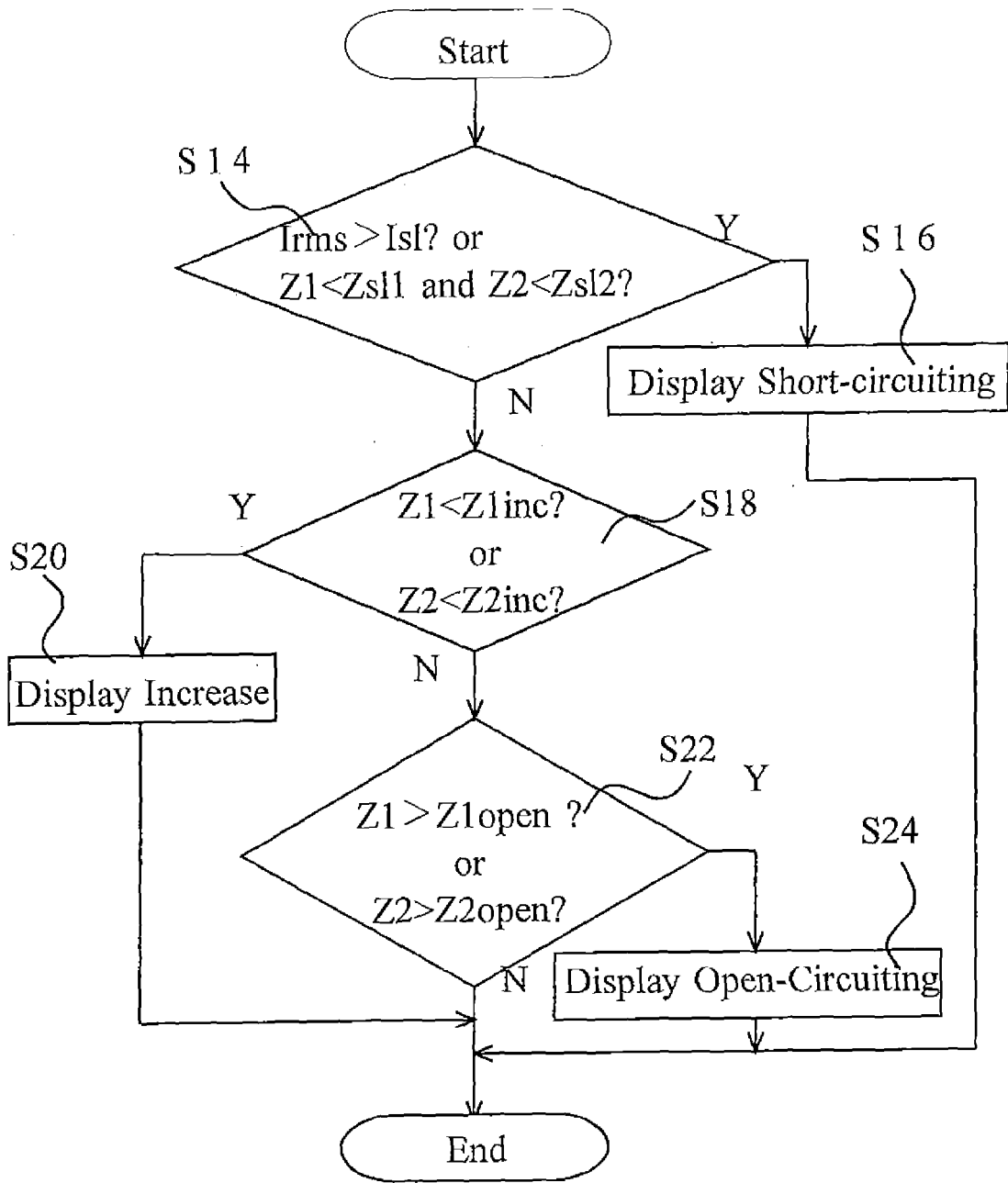


Fig.4

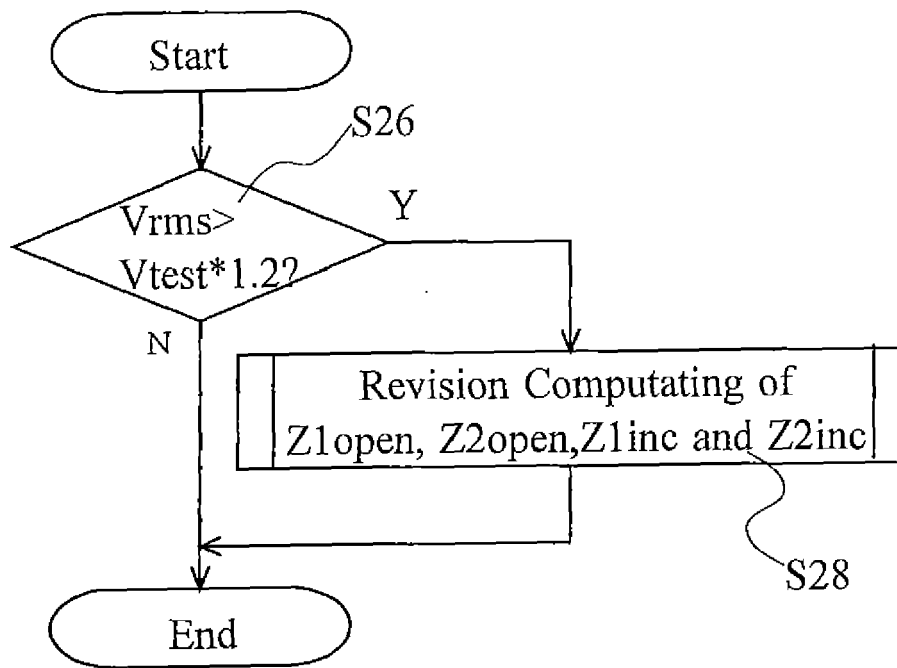


Fig.5

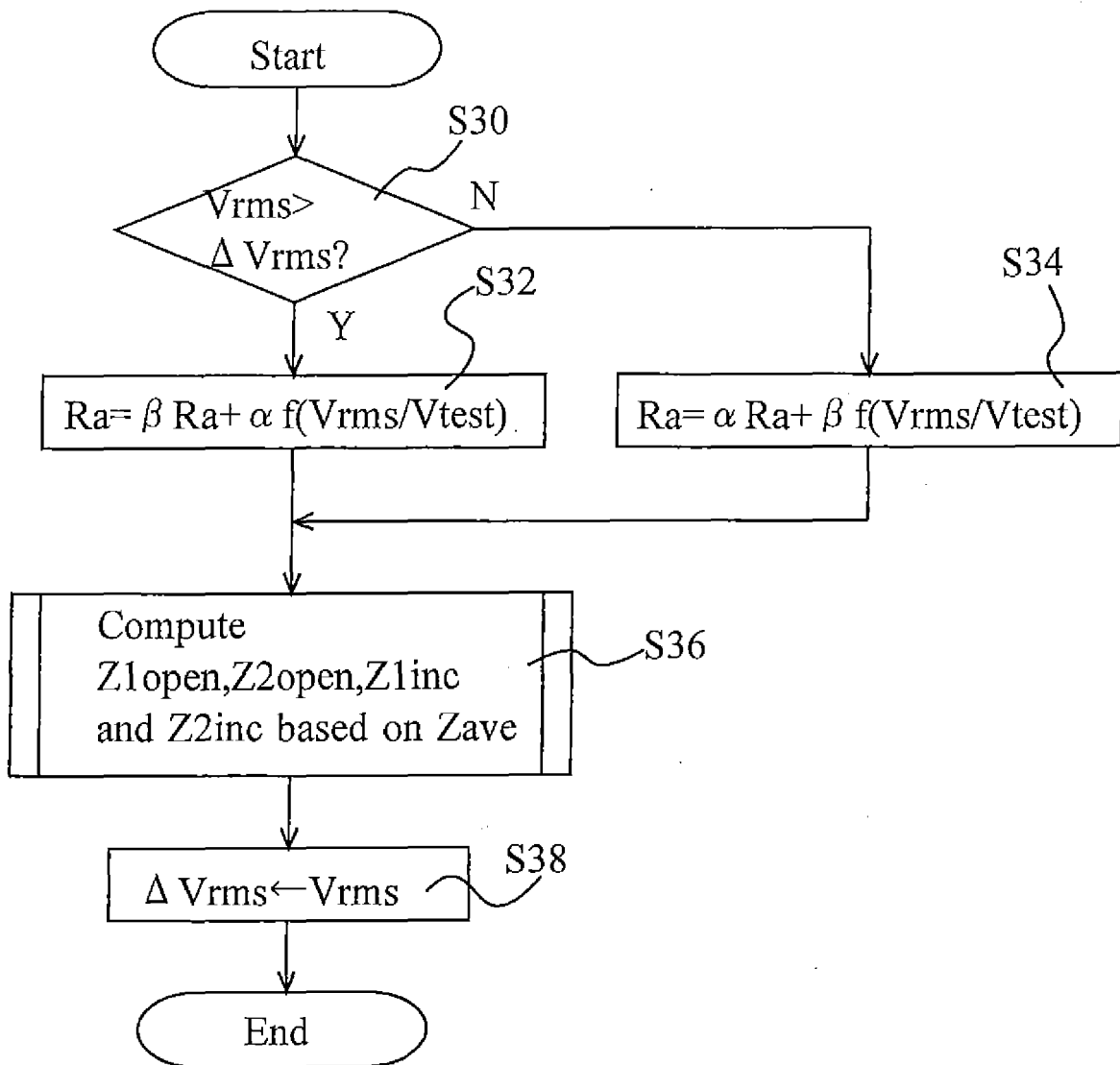


Fig.6

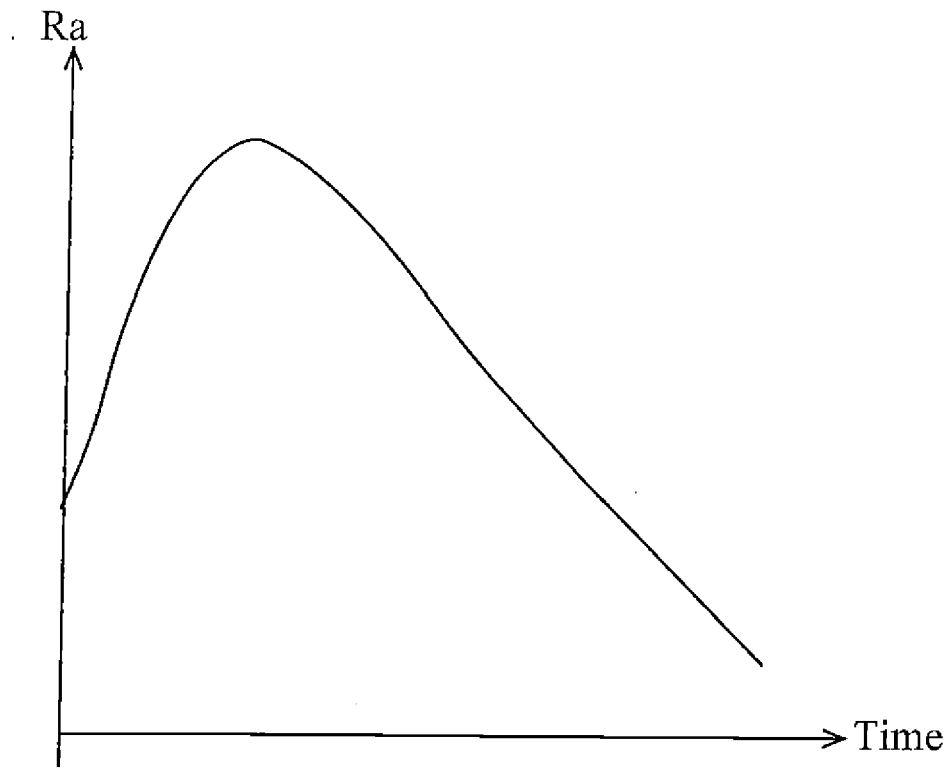


Fig.7

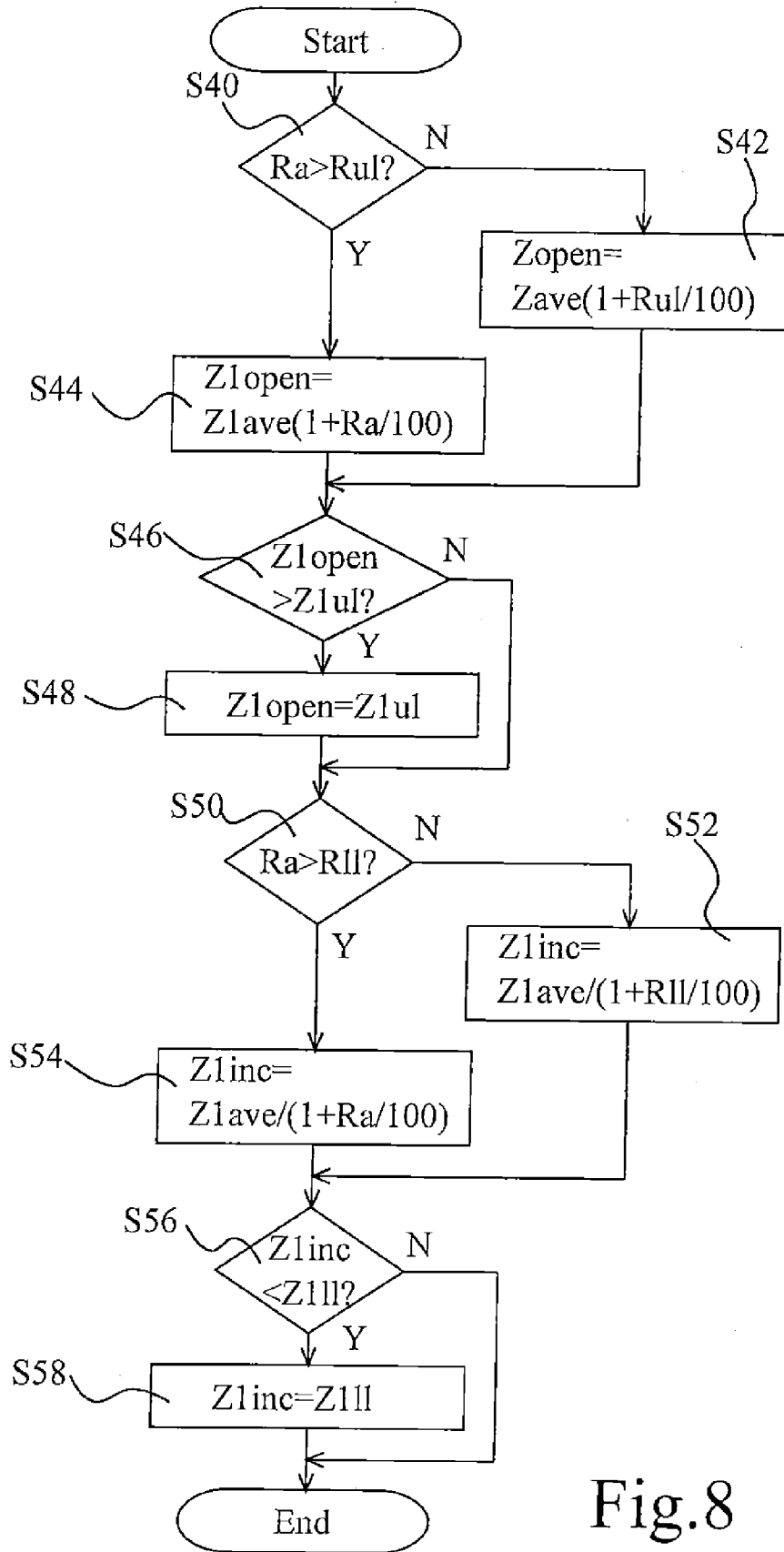


Fig.8

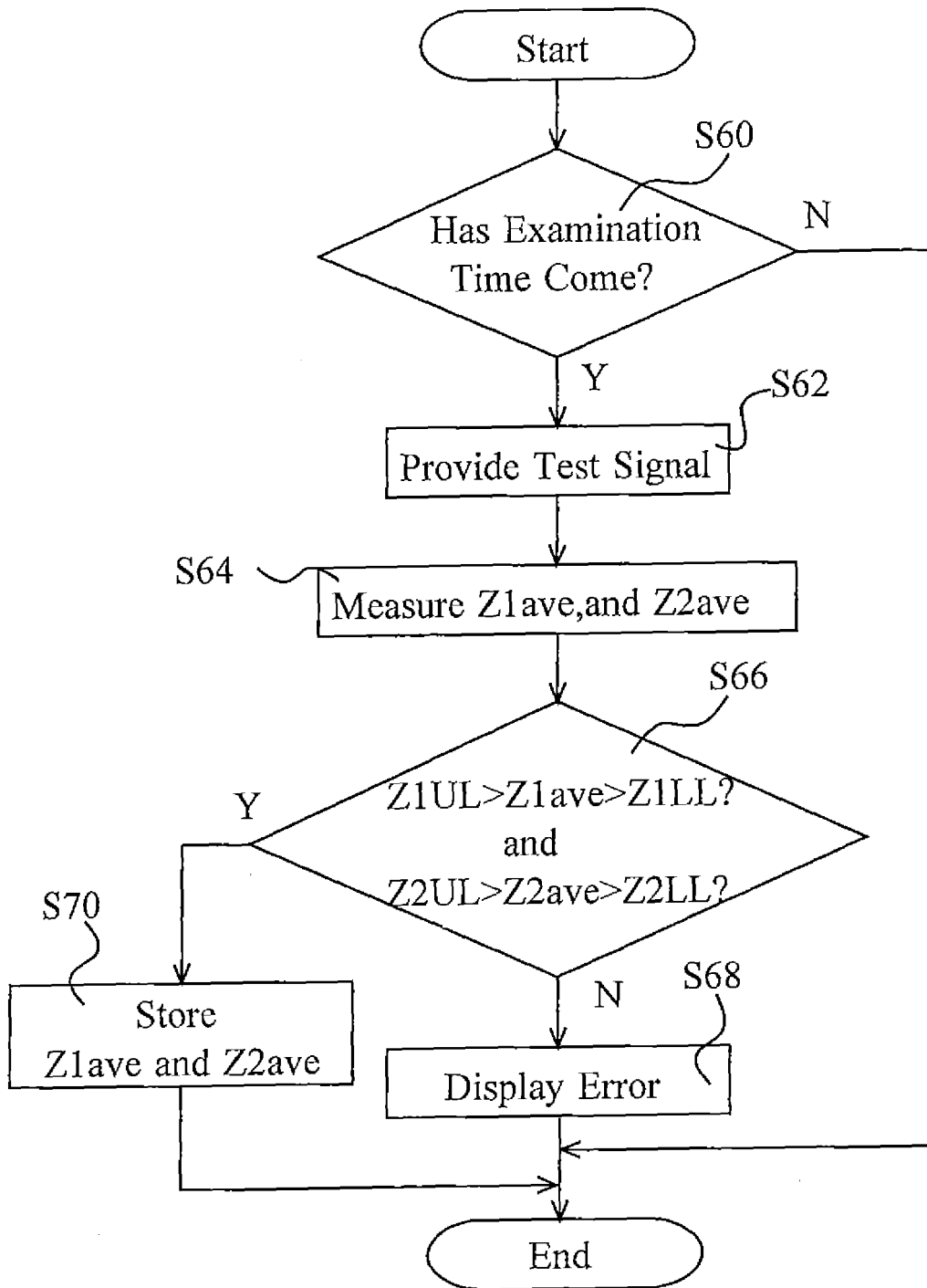


Fig.9



EUROPEAN SEARCH REPORT

Application Number
EP 13 15 1672

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A	JP 2007 037024 A (TOA CORP) 8 February 2007 (2007-02-08) * abstract; figure 1 * * paragraphs [0014], [0015] * -----	1-3	INV. H04R3/00 H04R29/00
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			H04R
1	Place of search Munich	Date of completion of the search 7 February 2013	Examiner Righetti, Marco
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