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(54) Scattered-light smoke detector

(57) A scattered-light smoke detector comprises an optoelectronic arrangement for measuring scatter signals (SB, SF) at, at least, a forward and a backward scatter angle, and evaluation electronics (12) for determining an alarm value in dependence of the ratio of the scatter signals (SB, SF) and comparing it with an alarm threshold. The scatter signals (SB, SF) are preprocessed and the alarm threshold is weighted. The weighting of the alarm threshold occurs in dependence on the relation of the scatter signals (SB, SF). There occurs additionally a weighting of the relation of the scatter signals, whereby the weighting factor is selectable in an application-specific manner.

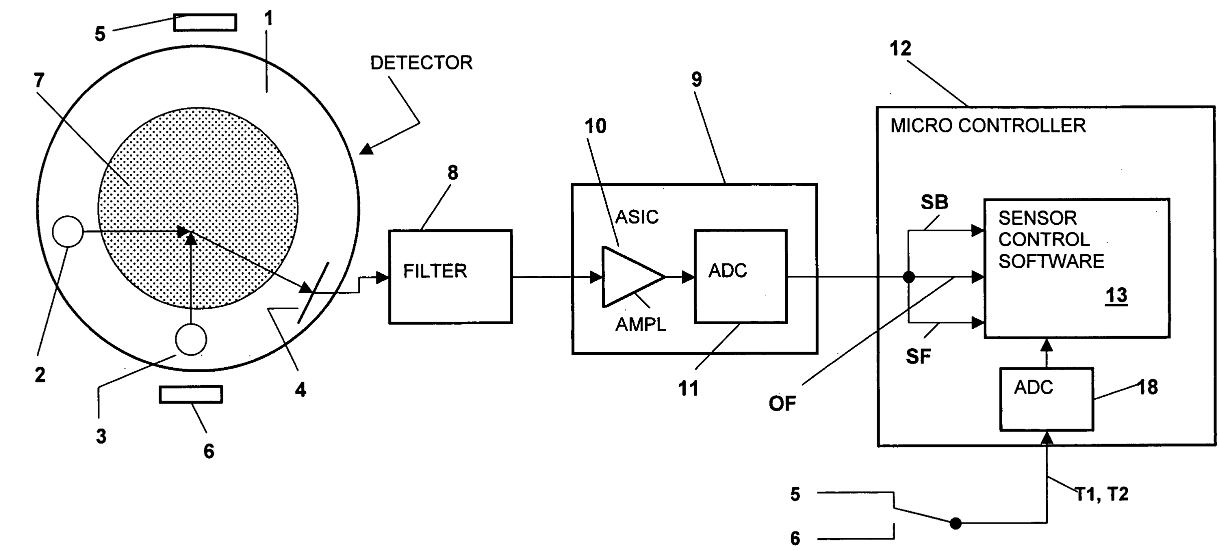

FIG. 1

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Description

[0001] The present invention relates to a scattered-light smoke detector with an optoelectronic arrangement for measuring scatter signals at a forward and a backward scatter angle, and with evaluation electronics for determining a measuring value and comparing it with an alarm threshold.

[0002] In the case of a scattered-light smoke detector of this type, described in EP-A-1 022 700 (= US-B-6 218 950), a light/dark quotient is calculated from the scatter signals, which results in the scatter signal of a dark aerosol receiving a higher weighting than the scatter signal of a light aerosol. The two scatter signals are added, and the sum is weighted by the said light/dark quotient.

[0003] The object of the present invention is to increase the safety from false alarms of the scattered-light smoke detectors of the initially stated type, at the same time assuring a response that is as rapid as possible.

[0004] This object is achieved, according to the invention, in that the scatter signals are preprocessed and in that the alarm threshold is weighted.

[0005] The weighting of the alarm threshold has the advantage that the type of fire is taken into account, and thereby the response is set optimally and late alarms are avoided. Moreover false alarms are reduced.

[0006] A first preferred embodiment of the scattered-light smoke detector according to the invention is characterized in that the weighting of the alarm threshold occurs in dependence on the relation of the scatter signals.

[0007] Preferably occurs additionally a weighting of the relation of the scatter signals, whereby the weighting factor is selectable in an application-specific manner and is selected in dependence on a set of the setting parameters of the detector which fulfils the requirements of the customer.

[0008] A second preferred embodiment of the scattered-light smoke detector according to the invention is characterized in that the preprocessing of the scatter signals includes a compensation of a so-called offset signal, which is formed by the output signal of the photodiode of the optoelectronic arrangement when not receiving scattered light.

[0009] A third preferred embodiment is characterized in that the preprocessing of the scatter signals includes a temperature compensation performed following the compensation of the offset signal.

[0010] A fourth preferred embodiment is characterized by at least one temperature sensor for measuring the ambient temperature of the detector, the signals of the at least one temperature sensor being supplied to the signal preprocessing. Two temperature sensors, symmetrically disposed in or on the housing of the detector, are preferably provided, from the signals of which a temperature signal is obtained.

[0011] A fifth preferred embodiment of the scattered-light smoke detector according to the invention is characterized in that the signals of the temperature sensors are supplied to a temperature preprocessing, at the output of which the said temperature signal is provided. A temperature value is preferably obtained from the temperature signal through analysis of the temperature and/or of the temperature increase.

[0012] A further preferred embodiment is characterized in that a determination of the short-time and long-time variance of the smoke signals is performed immediately after the preprocessing of the scatter signals, a large value of the variance being interpreted as an indication of interference. Preferably the determination of the variance is performed in a filter, which selects the median value from several consecutive values of the smoke signals, and selects the middle value in respect of the time sequence, and forms the difference from these two values, this difference being proportional to the fluctuations of the smoke signals.

[0013] Further preferred developments and improvements of the scattered-light smoke detector according to the invention are claimed in the dependent Claims 14 to 23.

[0014] The invention is explained more fully in the following with reference to an exemplary embodiment and the drawings, wherein:

Fig. 1 shows a schematic block graphical representation of a smoke detector according to the invention; and

Fig. 2 shows a schematic block diagram of the signal processing of the smoke detector of Fig. 1.

[0015] The smoke detector 1 represented in Figure 1, termed a detector in the following, includes two sensor systems, these being an optoelectronic system with two infrared-emitting light sources (IRED) 2 and 3 and a photodiode 4, and a thermal sensor system with two temperature sensors 5 and 6, consisting of NTC thermistors, for measuring the temperature in the environment of the detector 1. A measurement chamber 7 is formed between the light sources 2, 3 and the photodiode 4. The two sensor systems are disposed in a rotationally symmetrical housing (not shown), which is fixed in a socket mounted on the ceiling of a space to be monitored.

[0016] The temperature sensors 5 and 6 are disposed radially opposite one to the other, this having the advantage that they have a different behaviour of response to air flowing towards them from a given direction, so that the directional dependence of the response behaviour is reduced. The arrangement of the two light sources 2 and 3 is selected so that the optical axis of the photodiode 4 encloses an obtuse angle with the optical axis of the one light source, being the light source 2 according to the figure, and encloses an acute angle with the optical axis of the other light source, being the light source 3 according to the figure. The light of the light sources 2 and 3 is scattered by smoke entering the measurement chamber 7, and a portion of this scattered light falls on to the photodiode 4, the term forward scatter being used in the case of an obtuse angle between the optical axes of the light source and the photodiode, and the term backward scatter being used in the case of an acute angle between the said optical axes. The mechanical structure of the detector 1 does not constitute subject-matter of the present application, and is therefore not described more fully here; reference is made, in this connection, to EP-A-1 376 505 and to the literature references cited in this application.

[0017] It is known that substantially more scattered light is produced in the case of forward scatter than in the case of backward scatter, the two scattered-light components differing characteristically for different types of fires. This phenomenon is described in, for example, WO-A-84/01950 (= US-A-4 642 471), wherein it is disclosed, inter alia, that, for various smoke types, the ratio of the scattering in the case of a small scatter angle to the scattering in the case of a large scatter angle can be utilized for identifying the smoke type. It is also disclosed in this publication that the larger scatter angle could also be selected to be over 90°, which means an evaluation of the forward and backward scatter.

[0018] For the purpose of better discrimination between different aerosols, active or passive polarizing filters can be provided in the beam path on the transmitter and/or receiver side. As a further option, diodes which emit radiation in the visible-light wavelength range (see, in this connection EP-A-0 926 646) may be used as light sources 2 and 3 or, alternatively, the light sources may emit radiation of different wavelengths, for example, the one light source emitting red light and the other blue light.

[0019] The detector 1 performs a measurement, for example, every 2 seconds, the forward and backward scattered-light signals being generated sequentially. The signals of the photodiode, termed sensor signals in the following, have removed from them, in a filter 8, the coarsest interference of a defined frequency range, and then pass into an ASIC 9 which comprises, in essence, an amplifier 10 and an A/D converter 11. The digitized sensor signals, SB (backward scatter signal) and SF (forward scatter signal), termed scattered-light signals in the following, then pass into a microcontroller 12, which includes a sensor control software 13 for the digital processing of the scatter signals.

[0020] In addition to the scatter signals SB and SF, an offset signal OF is also supplied to the sensor control software. This offset signal is the output signal of the photodiode 4 when the latter does not receive scattered light from one of the two light sources 2 or 3. The signals, termed T_1 and T_2 of the two temperature sensors 5 and 6 are likewise supplied to the microcontroller 12 and, following digitization in an A/D converter 18, pass to the sensor control software 13.

[0021] The processing of the signals of the different sensors by means of the sensor control software 13 is now to be explained with reference to Fig. 2: firstly, there is performed a separate preprocessing both of the scatter signals SB and SF and of the offset signal OF, on the one hand, and of the signals T_1, T_2 of the temperature sensors 5, 6, on the other hand, in a preprocessing stage 14 and 15 respectively. In the smoke preprocessing 14, the fluctuations of the offset signal OF are smoothed in that the increase or the decrease of the sensor signals is limited to a predetermined value. The offset signal OF is then subtracted from the scatter signals. The preprocessing of the signals T_1 and T_2 in the temperature preprocessing 15 is necessary because there is a difference between the measured and the actual temperature that is determined by, *inter alia,* the thermal mass of the NTC thermistors 5 and 6 and of the detector housing, the position of the NTC thermistors in the detector 1, and influences of the detector and its environment that result in a delay. The measured temperature is compared with a reference value, and the actual temperature is then back-calculated with the use of a model. This actual temperature is linearized and limited in respect of its rise, so that there is provided, at the output of the temperature preprocessing 15, a temperature signal T which, inter alia, is supplied to the smoke preprocessing 14.

[0022] In the smoke preprocessing 14, following compensation of the scatter signals SB, SF with the offset signal, a temperature compensation is performed, in which a correction factor, by which the scatter signals SB, SF are multiplied, is obtained from the temperature signal T. If the detector 1 is a purely optical detector without temperature sensors 5 and 6, a single temperature sensor, which supplies a temperature signal, is provided in the detector.

[0023] In addition, the temperature signal T passes into a temperature difference stage, denoted by the reference 16, and into a maximum temperature stage, denoted by the reference 17. In the maximum temperature state 17, analysis is performed to determine whether the maximum of the temperature signal T exceeds an alarm value of, for example, 80°C (60°C in some countries). The temperature difference stage 16 examines how rapidly the temperature signal T rises. The output of the stage 16 is connected to an input of the stage 17, at the output of which is provided a temperature value T' which is used for the further signal processing.

[0024] The scatter signals preprocessed in the stage 14 pass into a median filter 19, which selects the median value from several, preferably five, consecutive values of the sensor signals. The median filter 19 also includes a so-called time shifter which, from the said five sensor signals, selects the middle value in respect of the time sequence, i.e., the third value. From these two values is then formed the difference, which is proportional to the fluctuations of the scatter signals and renders possible an estimation of the standard deviation of the scatter signals. This, in turn, enables interference to be calculated. The output signals of the median filter 19, termed smoke signals BW and FW in the following, pass into an extraction stage, denoted by the reference 20, for the purpose of obtaining a measurement value S. The reference BW denotes the backward smoke signal and the reference FW denotes the forward smoke signal.

[0025] In the extraction stage 20, a background compensation is performed, through a very slow filtering, in which interference, resulting essentially from dust, is compensated. In addition, the sum (BW + FW) of the smoke signals, hereinafter called measurement value S, and the relation of the smoke signals (quotient) BW/FW, hereinafter indicated with the reference number Q, are formed; the relation Q is raised to a higher power by an exponent C. The exponent C, which is normally between 0 and 2, depends on the intended application and on the intended installation site of the detector 1, or, in other words, on which type of fire, in particular, whether smouldering or open fire, is to be detected as a priority. Each detector 1 has a set of appropriate parameters, i.e., the so-called parameter set, which are adapted to the environment of its installation site and to the wishes of the customer.

[0026] In the case of the detector 1, the parameter set is dependent on, for example, the critical fire size, the fire risk, the risk to persons, the value concentration, the space geometry and on deceiving quantities, possible deceiving quantities being, for example, smoke not originating from a fire, exhaust gases, vapour, dust, fibres or electromagnetic interference.

[0027] Also performed in the extraction stage 20 is an optimization of the operating range of the A/D converter 11 (Fig. 1), and a determination of the short-time and long-time variance of the sensor signals and of the variations of noises in the signal. A large variance is an indication of interference, and can cause a reduction of the detection speed for certain parameter sets. Also performed in the stage 20 is a further, derived, analysis, in which it is calculated whether the sensor signal mainly increases over a relatively long period of, for example, 40 seconds, i.e., whether it increases monotonically, a monotonic increase of the sensor signal indicating a fire. The result of the derived analysis is used, in the case of some parameter sets, to adjust the speed of the signal processing.

[0028] If, for example, the sensor signal increases monotonically and the fire is evaluated in the subsequent evaluation stage 21 as an open fire, the signal processing speed can be quadrupled in order to achieve a more sensitive parameter set. The monotony is determined in that, from a number of, for example, 20 values of the sensor signal, certain pairs (V_n) and (V_{n-5}) for example, the first (V_1) and the sixth (V_6), the sixth (V_6) and the eleventh (V_{11}) value, and so forth, are selected, and the differences (V_n - V_{n-5}) are formed. A difference $V_n - V_{n-5} > 0$ corresponds to a monotonic increase of the sensor signal, and this is an indication of fire.

[0029] The output signal of the extraction stage 20, termed the measurement value S, is supplied both to the aforementioned evaluation stage 21 and to a stage, termed a slope regulator 22, for regulating the signal shape. To the evaluation stage there is supplied additionally the relation Q. The fire type, the so-called interference criterion, the so-called monotony criterion and the significance of the temperature are determined in the evaluation stage 21. The fire type is determined on the basis of the BW / FW ratio, possible types being smouldering fire, open fire or transient fire. The term transient fire refers to the transition from smouldering fire to open fire, when ignition of the fire is detected.

[0030] For the purpose of determining the interference criterion, the interference calculated from the standard deviation (median filter 19) is compared with a threshold value. For the purpose of determining the monotony criterion, the monotony of the sensor signal, calculated in the derived analysis in the extraction stage 20, is compared with a threshold value. The significance of the temperature is determined by comparison of the output signal of the temperature difference stage 16. An output signal > 20° means a significant temperature increase.

[0031] The output of the evaluation stage 21 is supplied to an event regulator 23, which controls both the slope regulator 22 and the maximum temperature 17. In the event regulator 23, the system decides whether and, if applicable, how the signal processing is to be modified. Such a modification is performed in the slope regulator 22, which constitutes an intelligent limiter of the increase/decrease of the sensor signal, and additionally determines the symmetry and gradient of the sensor signal.

[0032] In some parameter sets, it might be wished, for example, to forbid, limit or support purely optical alarms, i.e., those caused only by smoke. For this purpose, a method is used which limits the increase of the measurement value S to a defined value and, on the other hand, derives a defined maximum value from a delayed smoke signal and, depending on whether an ignition has occurred, uses one of the two values for the further processing. As a result, on the one hand, very rapid rises of the measurement value S caused by signal peaks are limited and, on the other hand, very slowly increasing signals caused by smouldering fires are emphasized (supported).

[0033] Two signals, being, on the one hand, a smoke value S' obtained by the processing just described and, on the other hand, a slow smoke Signal S^+, obtained by a very slow filtering, are provided at the output of the slope regulator 22. The smoke value S' is used for the further processing and, inter alia, is supplied to a bypass adder 25, to which the slow smoke signal S^+ is also supplied. In a stage (not shown) disposed immediately before the bypass adder 25, the smoke value S' is limited to a value which is dependent on the respective parameter set and to which the slow smoke value S^+ is then added in the bypass adder 25, the rise of the slow smoke signal S^+ being dependent on the respective parameter set and being less in the case of a robust parameter set than in the case of a sensitive parameter set. The bypass adder thus serves, in the case of a robust parameter set, to prevent an excessively prompt alarm in the case of a rapidly increasing smoke value S', and, in the case of a sensitive parameter set, to support the triggering of an alarm in the case of a slowly rising smoke value S'.

[0034] The smoke value S' and the Temperature value T' are each processed in the form of two values, W_{os} and W_{op}, and W_{ts} and W_{tp}, respectively, wherein:

- W_{os} denotes the weight of the optical path for summation
- W_{op} denotes the weight of the optical path for product formation
- W_{ts} denotes the weight of the thermal path for summation
- W_{tp} denotes the weight of the thermal path for product formation.

[0035] The fact that both a summation 26 and a multiplication 27 are performed has the advantage that, in the case of the summation 26, an alarm is triggered in the case of a high temperature value and also only a low smoke value, and, in the case of the multiplication 27, also in the case of a low temperature value and a low smoke value. The corresponding values are added and multiplied, which, together with the signal of the bypass adder 25 and the temperature value T', produces four signals which are supplied to a hazard-signal composition 28. From the four supplied signals, the latter selects, as an alarm signal, the signal having the highest value.

[0036] In a hazard-level acquisition 29, following the hazard-signal composition 28, the signal of the hazard-signal composition 28 is assigned to individual hazard levels and, in a hazard-level verification 30, a check is performed to determine whether the respective hazard level is exceeded over a defined period of, for example, 20 seconds. If this is the case, an alarm is triggered. The connections, indicated by broken lines, from the event regulator 23 to the maximum temperature 17, to the slope regulator 22, to the multiplication 27 and to the hazard-level verification 30 represent control lines.

[0037] As already mentioned, the relation Q is supplied to the evaluation stage 21 and is used there to determine the type of fire so that the event controller 23 can take the necessary steps for a possible change of the signal processing. Additionally, the relation Q is also supplied to the hazard-level acquisition 29 and is multiplied with the alarm threshold. That means in other words a weighting of the alarm threshold depending on the type of the detected fire.

Claims

1. Scattered-light smoke detector with an optoelectronic arrangement for measuring scatter signals (SB, SF) at a forward and a backward scatter angle, and with evaluation electronics (12) for determining an alarm value in dependence of the ratio of the scatter signals (SB, SF) and comparing it with an alarm threshold, **characterized in that** the scatter signals (SB, SF) are preprocessed and **in that** the alarm threshold is weighted.

2. Scattered light smoke detector according to claim 1, **characterized in that** the weighting of the alarm threshold occurs in dependence on the relation of the scatter signals (SB, SF).

3. Scattered light smoke detector according to claim 2, **characterized in that** additionally a weighting of the relation of the scatter signals occurs, whereby the weighting factor is selectable in an application-specific manner.

4. Scattered-light smoke detector according to claim 3, **characterized in that** the weighting factor is selected in dependence on a set of the setting parameters of the detector (1) which fulfils the requirements of the customer.

5. Scattered-light smoke detector according to claim 4, **characterized in that** the weighting factor is between zero and two.

6. Scattered-light smoke detector according to any one of claims 1 to 5, **characterized in that** the preprocessing (14) of the scatter signals (SB, SF) includes a compensation of a so-called offset signal (OF), which is formed by the output signal of the photodiode (4) of the optoelectronic arrangement when not receiving scattered light.

7. Scattered-light smoke detector according to any one of claims 1 to 6, **characterized in that** the preprocessing (14) of the scatter signals (SB, SF) includes a temperature compensation performed following the compensation of the offset signal (OF).

8. Scattered-light smoke detector according to claim 7, **characterized by** at least one temperature sensor (5, 6) for measuring the ambient temperature of the detector (1), the signals of the at least one temperature sensor (5, 6) being supplied to the signal preprocessing (14).

9. Scattered-light smoke detector according to claim 8, **characterized in that** two temperature sensors (5, 6), disposed in or on the housing of the detector (1), are provided, from the signals (T_1, T_2) of which a temperature signal (T) is obtained.

10. Scattered-light smoke detector according to claim 9, **characterized in that** the signals (T_1, T_2) of the temperature sensors (5, 6) are supplied to a temperature preprocessing (15), at the output of which the said temperature signal (T) is provided.

11. Scattered-light smoke detector according to claim 10, **characterized in that** a temperature value (T') is obtained from the temperature signal (T) through analysis of the temperature (17) and/or of the temperature increase (16).

12. Scattered-light smoke detector according to any one of claims 4 to 11, **characterized in that** a determination of the short-time and long-time variance of the smoke signals (BW, FW) is performed immediately after the preprocessing (14) of the scatter signals (SB, SF), a large value of the variance being interpreted as an indication of interference.

13. Scattered-light smoke detector according to claim 12, **characterized in that** the determination of the variance is performed in a filter (19), which selects the median value from several consecutive values of the smoke signals (BW, FW), and selects the middle value in respect of the time sequence, and forms the difference from these two values, this difference being proportional to the fluctuations of the smoke signals (BW, FW).

14. Scattered-light smoke detector according to claim 12 or 13, **characterized in that** a measurement value (S) is obtained, in an extraction stage (20), from the weighted ratio of the smoke signals (BW, FW), and this measurement value (S) is both subjected to an evaluation (21) and supplied to a stage, termed a slope regulator (22) in the following, for regulating the signal shape.

15. Scattered-light smoke detector according to claim 14, **characterized in that**, in the evaluation (15) of the measurement value (S), a check is performed to determine whether the latter increases monotonically over a given period, and such a monotonic increase of the measurement value (S) is interpreted as an indication of a fire.

16. Scattered-light smoke detector according to claim 15, **characterized in that** the monotony of the measurement value (S) is determined **in that**, from a number of values of the measurement value (S), given pairs are selected and the differences are formed.

17. Scattered-light smoke detector according to claim 16, **characterized in that** there is performed in the slope regulator (22) a limitation of the measurement value (S) in which the latter can be limited to a given level and/or can be amplified through addition of a booster signal, the booster signal both preventing a rapid rise of the measurement value (S) due to signal peaks and also accentuating slow signal rises in the case of smouldering fires.

18. Scattered-light detector according to claim 17, **characterized in that**, in the slope regulator (22), a slow smoke signal (S^+) is obtained through a very slow filtering of the measurement value (S).

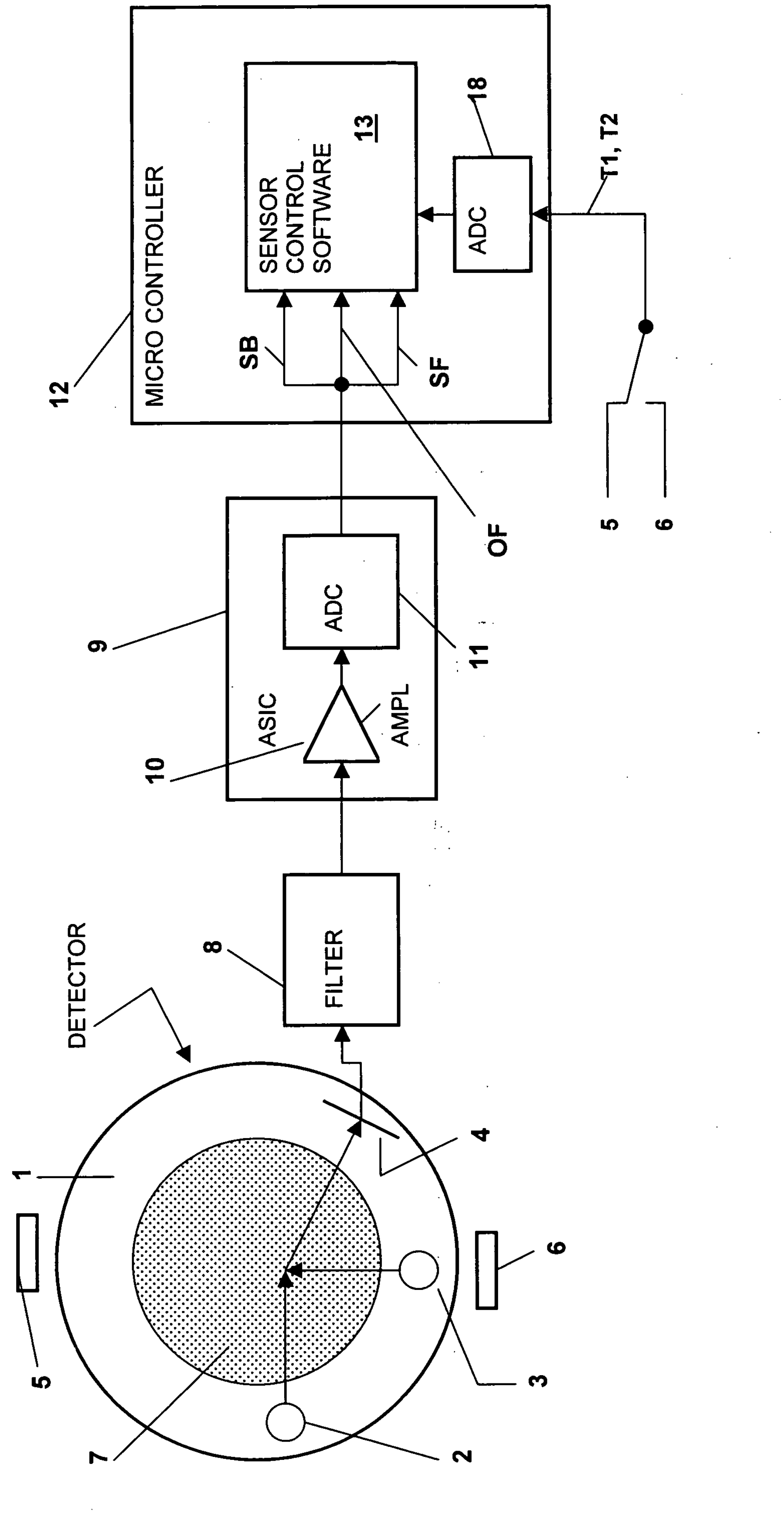
19. Scattered-light detector according to claim 11 and any one of claims 14 to 18, **characterized in that** the alarm value is determined from the output signal of the slope regulator (22), termed smoke value (S') in the following, from the slow smoke signal (S^+) and from the temperature value (T').

20. Scattered-light smoke detector according to claim 19, **characterized in that** both a summation (26) and a product formation (27) are performed with the smoke value (S') and the temperature value (T').

21. Scattered-light smoke detector according to claim 19, **characterized in that** the smoke value (S') and the temperature value (T') are each processed in the form of two values (W_{os}, W_{op} and W_{ts}, W_{tp} respectively), W_{os} being the weight of the optical path for summation, W_{op} being the weight of the optical path for product formation, W_{ts} being the weight of the thermal path for summation and W_{tp} being the weight of the thermal path for product formation.

22. Scattered-light smoke detector according to claim 21, **characterized in that** the signal having the highest value is selected from the result of the summation and product formation and used as an alarm signal.

23. Scattered-light smoke detector according to claim 22, **characterized in that** an assignment to different hazard levels and, subsequently, a verification of these hazard levels, is performed through a comparison of the alarm signal with different alarm thresholds.


MICRO CONTROLLER
12
SENSOR
CONTROL
SOFTWARE
13
ADC
18
T1, T2
SB
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OF
5
6
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ADC
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FILTER
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DETECTOR
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FIG. 1

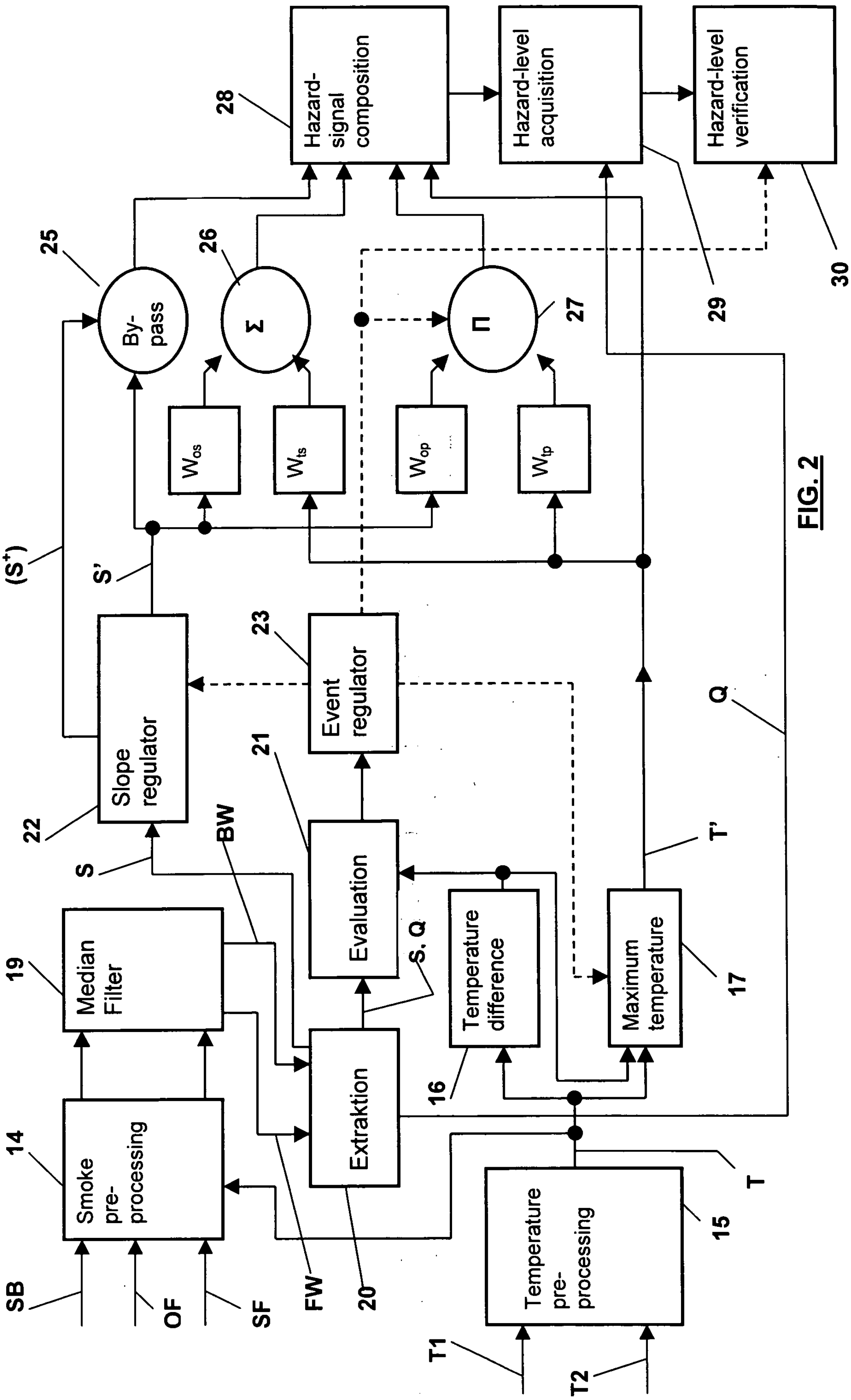
Hazard-signal composition
Hazard-level acquisition
Hazard-level verification
28
25
26
27
29
30
By-pass
Σ
Π
W_{os}
W_{ts}
W_{op}
W_{tp}
(S+)
S'
Slope regulator
Event regulator
22
23
21
BW
S
Evaluation
Median Filter
19
S. Q
Temperature difference
Maximum temperature
16
17
T'
Q
Smoke pre-processing
14
Extraktion
20
Temperature pre-processing
15
T
SB
OF
SF
FW
T1
T2

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 04 01 7433

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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X	US 2004/066512 A1 (SPRENGER RALF ET AL) 8 April 2004 (2004-04-08) * paragraphs [0006] - [0009] * * paragraph [0026] * * claims 1-3 * -----	1,6	
Y	US 5 293 049 A (MOREY RICHARD K ET AL) 8 March 1994 (1994-03-08) * column 1, lines 34-38 * * column 3, lines 29-53 * -----	12,13	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G08B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	20 December 2004	Meister, M

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 01 7433

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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20-12-2004

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