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(54) **Smoke detector**

(57) A smoke detector uses a detector assembly in the form of a sensor and light source. This can be formed as a packaged circuit and can therefore be low cost and have a small volume. The detector assembly is mounted

in a housing including a reflector, which redirects the light source light back towards the detector assembly. The sensor receives a changing signal in the presence of smoke resulting from light scattering.

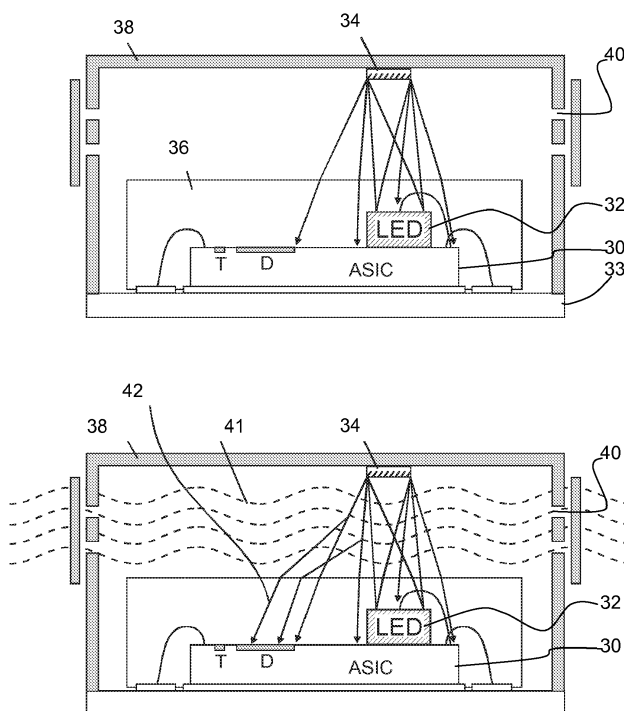


FIG. 3

Description

[0001] This invention relates to smoke detectors.

[0002] Smoke detectors are very popular in office buildings, public places and homes. They are often in the form of a cylindrical or dome-shaped box mounted on the ceiling. When smoke is detected, the alarm goes off or the detector sends an electrical or RF signal to a central security system to trigger a global alarm of the whole building.

[0003] Smoke detectors often use one of two operating principles: optical and ionization.

[0004] In an optical smoke detector, there are basically a light source and a light detector mounted separately at two different locations in the casing of the device. The light beam emitted from the light source does not directly fall on the detector under the smoke-free condition. When smoke appears in the space between the detector and the light source, light is scattered and thus partially enters the detector and an alarm signal is triggered.

[0005] In an ionization smoke detector, there is a weak radioactive source (1 μ Ci of radioactive americium-241). The radiation passes through an ionization chamber, which ionizes air molecules inside the chamber. In the chamber, there are two electrodes facing each other, between which a small, constant ionized current flows. In the condition of no smoke, this current is constantly present. When smoke appears in the chamber, smoke particles neutralize the air ions, which reduces the ionization and interrupts this current, setting off the alarm.

[0006] In conventional types of smoke detector, most components are discrete devices and the whole system is often bulky, contains many parts and is therefore expensive. The power consumption of these devices is often large, in the order of mW, which needs a sizable battery to ensure a long operating period.

[0007] There is therefore a need for a low power, low volume smoke detector.

[0008] According to the invention, there is provided a smoke detection system, comprising:

- a housing;
- a light source;
- an integrated circuit comprising an optical detector, wherein the light source and the integrated circuit together comprise a detector assembly mounted inside the housing;
- a reflector mounted inside the housing opposite to the detector assembly and to which the light source output is directed; and
- a processor for deriving a signal indicating the presence of smoke in the cavity based on the change of light reception by the optical detector.

[0009] The invention uses a detector assembly in the form of a sensor and light source. This can be formed as a packaged circuit and can therefore be low cost and have a small volume. The detector assembly is mounted

in a housing including a reflector, which redirects the light source light back towards the detector assembly.

[0010] The invention provides an integrated optical smoke detector that has much more compact form-factor, low cost, and low power consumption. The light source is preferably mounted directly on a silicon die, i.e. over the integrated circuit. The silicon die contains the photo-detector or photodetectors and preferably also the processor, in the form of an application specific integrated circuit (ASIC) to control the system and perform signal processing. The light source can be a bare LED die mounted on the silicon die, an OLED, or integrated silicon-based light source built inside the silicon die.

[0011] The optical detector can comprise a detector laterally spaced from the reflected path of the light source output when the cavity is clear of light scattering material. The detector thus has a very low signal in the absence of smoke, but is near enough to the optical path that light scattering caused by smoke will provide a detector reading.

[0012] In another example, the optical detector comprises a first detector in the reflected path of the light source output when the cavity is clear of light scattering material, and a second detector laterally spaced from the reflected path of the light source output when the cavity is clear of light scattering material. This enables differential signal processing, in that the light scattering will reduce the light intensity to the first detector and increase the light intensity to the second detector.

[0013] Thus, the processor can be adapted to determine a difference between the first and second detector signals and derive the signal indicating the presence of smoke from the difference signal.

[0014] The (or each) detector can comprise a photodiode or photodiode array.

[0015] The integrated circuit can further comprise a temperature sensor. This can be used to provide additional information from which to determine a fire event, and/or it can be used to provide compensation for variations in circuit element performance dependent on temperature.

[0016] The system can further comprise a radio frequency transmission system for sending a wireless smoke detection message. This enables the detector to be low power, as the alarm signal can be generated by a remote unit. An energy scavenging unit and an energy store can be provided so that the detector can be wireless (i.e. not require connection to the mains) but also be battery-free. The system can be formed as a wireless sensor node.

[0017] The invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 shows the circuit of a known optical joystick which can be used to implement the invention;

Figure 2 shows the mechanical structure of a known optical joystick which can be used to implement the invention;

Figure 3 shows a first example of smoke detector of the invention in a smoke-free and a smoke-filled environment;

Figure 4 shows a second example of smoke detector of the invention in a smoke-free and a smoke-filled environment;

Figure 5 shows an example output from the detector of Figure 4; and

Figure 6 shows the electrical components of an example of smoke detection system of the invention.

[0018] The invention provides an integrated optical smoke detector that has much more compact form-factor, low cost, and low power consumption. In this device, a light source is mounted directly on a silicon die or formed as a structure within the silicon die. The silicon die also contains one or more photodetectors and an application specific integrated circuit (ASIC) to control the system and perform signal processing. The light source can be a bare LED die mounted on the silicon die, an OLED, or integrated silicon-based light source built inside the silicon die.

[0019] The invention is based on the application of optical technology which is currently being developed by the applicant in the field of input devices (and in particular for a so-called optical joystick) to the field of smoke detection.

[0020] To explain the underlying technology as applied to optical joysticks, reference is made to patent applications W02010/035170, WO 2010/020906, and W02009/125360.

[0021] Figures 1 and 2 are repeated from WO 2010/035170.

[0022] Figure 1 shows an overall configuration of the circuitry of the optical joystick which has technology aspects which can be used to implement the present invention.

[0023] As shown in Figure 1, a plurality of photodetectors D1 to D4 have a light sensing function. The arrangement of Figure 1 shows, for example, the detectors D1 to D4, but any suitable number n of detectors D1 to Dn can be provided. In the case of the optical joystick, these function to obtain a required angular detection function. Each of the detectors D1 to D4 may be composed of a plurality of light sensitive elements, such as photo diodes or photo transistors.

[0024] A light emitting element S is provided adjacent to the plural detectors D1 to D4, and is arranged for emitting light which can be reflected by a reflecting unit 5 (not shown in Figure 1, explained hereinafter) to obtain incident light on each of the plurality of detectors D1 to D4 by means of the reflecting unit 5. The light source S may be composed of a plurality of light emitting elements, such as LEDs.

[0025] A subset of the plurality of detectors D1 to D4, in the present case the first and second detectors D1 and D2 are connected to a first processing unit 6, arranged for a pre-processing of corresponding output signals gen-

erated by the respective first and second detectors D1 and D2.

[0026] In a similar manner, a further subset of the plurality of detectors D1 to D4, and specifically the third and fourth detectors D3 and D4 are connected to a second processing unit 7 for providing a corresponding pre-processing of output signals of the respective subset of detectors (the detectors D3 and D4), as in the case of the first processing unit 6.

[0027] The pre-processed output signals of the plurality of detectors D1 to D4, and specifically the output signals of the first and second processing units 6 and 7 are communicated to a controller 8 having the function of a data evaluation and control means. The controller 8 is adapted for performing on the one hand the data evaluation on the basis of the pre-processed output signals of the plurality of detectors D1 to D4, and on the other hand to perform a control of the entire detection system. This includes the controlled driving of the light source S for emitting corresponding light.

[0028] The output signals of the plurality of detectors D1 to D4 are in addition communicated to a further controller 8a also having the function of a data evaluation and control means for a push button command detection.

The further controller 8a is adapted for performing the data evaluation on the basis of the output signals of the plurality of detectors D1 to D4. Specifically, based on the supply of the output signal of each of the plurality of detectors, a common signal is produced (by taking the sum of all signals), and a click signal (Z detection signal) is generated and then fed to the (central) controller 8.

[0029] The controller 8 may have a connection to any further device and corresponding control means thereof depending upon the device or apparatus to which the detection system is connected or which the detection system is applied to.

[0030] Figure 1 shows the circuit structure as general connections for transmitting and/or receiving data, as well as current and/or voltage signals between the various components of the circuitry shown.

[0031] While Figure 1 shows the basic elements or components of the circuitry and hardware of the joystick, Figure 2 shows the cross-sectional view of the arrangement of the joystick.

[0032] The cross-sectional view of Figure 2 depicts a package (or casing) 9, wherein on a substrate 10 arranged in a cavity 11 of the package 9, the plurality of photodetectors D1 to D4 is arranged or embedded. The substrate is fixed to the package 9, preferably in the central portion in the cavity 11 thereof by means of a metal layer 12.

[0033] The light source S schematically shown in Figure 1, is arranged on the substrate 10 preferably but not necessarily at a central portion thereof as a separate component, or may be embedded in the substrate 10, to emit light basically in a direction upward in Figure. 2.

[0034] While the light source S is preferably located at the central portion of the substrate 10, the plurality of

detectors D1 to D4 is arranged around the light source S. The electrical connections between the package and the detectors D1 to D4 and the light source S are provided by bonding wires, and the electrical connections of the package to the outside can be ball-grid; SMD (surface mounted devices), etc., but also flexible connections are possible.

[0035] The cavity 11 of the package extends above the light source S and the detectors D1 to D4 surrounded by sidewalls 13 of the package 9. Hence, the substrate 10 in conjunction with the detectors D1 to D4, the light source S and the corresponding bonded connections is commonly housed inside the package, which may be provided in the form of an IC package. In this case the detection system is implemented in the IC package.

[0036] Above the light source S there is a touch surface on a movable object preferably provided in the form of a knob 14, which can be touched for operation of the joystick by the user. The knob 14 as shown in Figure 2 basically constitutes a cover over the package 9 and the cavity 11 thereof, and may be movable to a certain extent relative to the package 9. To this end, the knob 14 is flexibly supported by a flexible suspension mechanism which is preferably provided in the form of a spring 15 which allows the knob 14 to tilt a few degrees around a virtual point when the force from a user's finger is applied. Due to the elastic support of the knob 14 on the package 9 by the spring 15 the knob can return to the central position or rest position when the force of the user's finger is removed, this corresponding to a released position of the knob 14 (movable object). It also enables a push button detection, since the spring has two stable positions. When the reflective surface is moved nearer to the light source, the intensity reaching the sensors increases, whereas the differential signals (used to derive the x and y coordinates) remain unchanged. Thus, the click function can be detected uniquely.

[0037] At the lower portion of the knob 14, on the surface thereof opposite to the cavity 11 of the package 9, a reflecting unit 5 is arranged in such a manner as to face the light source S. The reflecting unit 5 is therefore in a functional relationship or operational connection with the knob (movable object) 14 and may be provided in the form of a mirror which can have a symmetrical shape such as a square shape or a circular shape, and the reflecting unit 5 may be mounted at the central portion of the knob 14 which may be provided in the form of a protruding portion extending in a direction downward in Figure 2 towards the substrate 10, and in particular towards the light source S.

[0038] Hence, for obtaining the functional or operational connection to the knob 14 the reflecting unit 5 is mounted to the bottom of the knob 14, that is, the lower surface of the knob 14, whereas the upper surface of the knob 14 constitutes the touch surface for any operation by the user.

[0039] The dimensions of the complete device are about a few millimetres, but can be larger if required.

[0040] The plural detectors D1 to D4, the light source S and further components may be arranged in an integrated manner on the substrate 10 of the package 9, so that an on-chip solution can be obtained.

[0041] The invention involves the use of the same conceptual layout of light source and detector arrangement. A reflector is provided, but this is fixed in position, so that the spring arrangement and knob is not needed. The detector arrangement also does not need to be able to discriminate between illumination in different directions.

[0042] Thus, the invention provides an integrated smoke detector which comprises a silicon die that contains an ASIC, a light source mounted on the silicon die, and at least one photodetector integrated on the silicon die.

[0043] Figure 3 shows the components of an example of smoke detector of the invention, in a smoke free condition (top image) and in a smoke filled environment (bottom image).

[0044] The device comprises an ASIC 30 onto which is mounted an LED chip 32. The LED emits light upwardly towards a reflector 34 which folds the light path back down to the ASIC. A detector D is provided as part of the ASIC (i.e. it is an integrated circuit component). The ASIC 30 and LED 32 are encased in a transparent package 36 which protects the dies from corrosion due to the environment but still lets light pass through. Alternatively, the ASIC 30 and LED 32 can also be encapsulated by a transparent lid (made of e.g. glass) which covers a cavity that contains the ASIC 30 and LED 32.

[0045] The package 36 is mounted within a casing 38 which defines a cavity. The cavity is not sealed, but has gas entry and exit ports 40 to allow the flow of gas through the cavity, as shown in the lower figure.

[0046] The entry and exit ports are designed to prevent light entering the cavity. For example, openings are provided, as well as a spaced light absorbing cover. The internal surface of the casing can also be light absorbing. Thus, the detector D is insensitive to variations in light level outside the cavity, and the cavity is illuminated only by the LED.

[0047] Figure 3 also shows that a temperature sensor T may also be integrated as part of the ASIC.

[0048] The ASIC is wirebonded to an underlying lead-frame 33. Other techniques of interconnecting the ASIC to the outside world, such as through-silicon-vias are also possible.

[0049] The light source can comprise a bare LED die provided over the silicon die as shown in Figure 3. However, it can instead comprise an Organic Light Emitting Diode (OLED), which can be formed by thin-film deposition and patterning directly on top of the silicon die. Alternatively the light source may also be a silicon device such as a P-N junction integrated in the silicon die that can emit light when a current is injected through the junction. In Figure 3, the LED 32 is stacked on top of the ASIC 30. An alternative is that the LED 32 is mounted side-by-side with the ASIC 30 on the same lead-frame 33.

[0050] The photodetectors may be photodiodes, phototransistors, or photoresistors. The optional temperature sensor T integrated in the same silicon die is for measuring the temperature of the die to compensate for the temperature influence on the circuit performance. The temperature sensor can for example comprise a simple diode, transistor, resistor or a so-called Proportional To Absolute Temperature (PTAT) sensor.

[0051] The wirebonding is to a lead-frame and connects to a number of I/O pins. There are bondwires connecting the LED die to the silicon die and from the silicon die to the I/O pins of the leadframe.

[0052] In the first embodiment of Figure 3, the silicon die comprises one photodetector D. The reflector is arranged such that in the condition of no smoke, the specularly reflected light impinges only on an area in close proximity to the photodetector, but does not significantly overlap on the photodetector D. Thus, the detector D is basically outside the spread of the light from the reflector 34. Therefore under the smoke-free condition, the signal level of the photodetector is substantially zero, or calibrated as the "no-smoke" level.

[0053] When smoke is present in between the reflector and the silicon die, light is scattered by smoke particles. Consequently, some scattered light enters the photodetector, which changes the output signal to a non-zero level. If the signal level is higher than a pre-determined threshold, an alarm signal is triggered. The smoke is shown as 41 and the scattered light is shown as 42.

[0054] Smoke is often associated with high temperature, although high temperature is not alone a reliable indicator of the presence of fire or smoke so that temperature sensing alone is not sufficient. However, temperature sensing can provide additional information which can be used for the fire detection decision making. An integrated temperature sensor T is used to provide the additional information concerning the temperature, and this can be used to enhance the accuracy of the smoke detection algorithm.

[0055] More importantly, the temperature sensor can be used to subtract the influence of temperature on the detector signals in particular from the total output signal, thereby to increase the accuracy of the detection and to eliminate false alarms due to temperature influence of the detector signals. By performing a temperature calibration in the smoke-free condition, the temperature behaviour of the photodetector can be determined and later during operation, can be subtracted from the measured signal.

[0056] The detector may be operated in duty cycles, so that every predetermined period of time, e.g. every a few seconds, or few tens of seconds, the light source and the detection circuit are powered for a short duration (e.g. a number of ms) just enough to detect the air situation. After that the circuit is put to standby for the rest of the time. With the duty cycled operation, the power consumption can be largely reduced. A typical average power needed for such device is in the order of μW or a few

tens of μW .

[0057] Due to the high degree of integration, the smoke detector has a very compact form-factor.

[0058] Figure 4 shows a second implementation in which the silicon die comprises two photodetectors D0 and D1. One serves as a reference detector (D0) and the other as a detection detector (D1). The other components in Figure 4 are identical to Figure 3 and the same reference numbers are used.

[0059] The two photodetectors are connected in a differential circuit to detect the difference between the detection and reference signals, so that the output signal is equal to signal D1 minus signal D0.

[0060] The reflector is arranged such that the specularly reflected light impinges only on the reference photodetector, but not significantly on the detection photodetector. Under the smoke-free condition, only the reference photodetector receives light and the differential signal is defined as the no-smoke level.

[0061] When smoke is present between the reflector and the silicon die, light is scattered by smoke particles. Consequently, some light enters the detection photodetector while light intensity slightly reduces at the reference photodetector due to the diffusivity of smoke. These changes make the differential signal increase and if the signal is higher than a pre-determined threshold, an alarm signal is triggered.

[0062] The use of the differential signal mode reduces the influences of e.g. aging of the light source, temperature change and drift, any residual ambient light, etc., which are common signals for the two photodetectors therefore are cancelled in the differential signal. An integrated temperature sensor may still be useful in this case to eliminate any temperature effect that might be present outside the differential circuit.

[0063] Figure 5 shows an example of signals from a smoke detector made in accordance with the design shown in Figure 4.

[0064] The plot shows the differential signal and shows the signal increases which arise when smoke is provided to the area surrounding the detector. The temperature is varied over time, and this temperature variation results in a varying differential signal as a result of the effect of temperature on circuit components which are not cancelled by the differential operation. The dotted line in the plot shows how the circuit components have an output which varies with temperature.

[0065] The smoke signal can be obtained by subtracting the total signal from the signal caused by temperature only. This temperature-only function can be obtained as part of a calibration process as outlined above.

[0066] In one embodiment the smoke sensor is applied as part of an ultra low power Wireless Sensor Node (WSN). Power usage of such a WSN is so low that it may be powered by scavenged energy, for example a small photo-voltaic cell suffices to keep a battery or super capacitor sufficiently charged to operate the node. An example of such a sensor node is described in the paper

of G. Chen et al. "A Millimeter-Scale Nearly-Perpetual Sensor System with Stacked Battery and Solar Cells" Proc. ISSCC, 2010.

[0067] Scavenged sensor nodes have one notable benefit: neither wiring, nor battery replacement is needed to supply power to the node. This means installation and maintenance cost are kept to a minimum. One well known drawback of smoke sensors powered with replaceable batteries is that they sound an alarm when battery replacement is imminent, which could be in the middle of the night.

[0068] The scavenged sensor can trigger a mains powered alarm by a radio link, so it only needs to be able to power a low power radio transmission, rather than the alarm itself.

[0069] Figure 6 shows a system diagram of a scavenged WSN. It comprises a scavenging element 60, an energy storage 62, a controller 64, a radio 66 (transmission and optionally also reception), and a number of sensing elements 68. One of the sensing elements is the smoke detector according to this invention. Another sensing element may be the optional temperature sensor mentioned above. Optionally, other sensing elements (e.g. detecting CO₂, CO, other toxins, ...) may be present to form a more comprehensive "hazard sensor".

[0070] Power conversion stages 70 are also shown that interface between the scavenging element 60 and the energy store and between the energy store and the controller (which in turn powers the sensors and radio circuitry). These enable optimal storage and extraction of energy from the energy store.

[0071] The electronics of the WSN can also be integrated in the same silicon die that contains the ASIC of the smoke detector.

[0072] Since fire often generates high temperatures and emission of CO₂, CO and other gases as well as smoke, signals from these factors may also be smartly combined inside the system to detect fire events more accurately.

[0073] The scavenging element extracts a small amount (typically tens or hundreds of microwatts) of power out of the ambient and converts it into electrical energy. In a typical embodiment the scavenging element comprises of one or more photo-voltaic cells, which are able to generate the necessary energy even under typical indoor lighting conditions. In specific — e.g. industrial — settings also thermal and/or vibration scavenging may be used. Alternatively, energy may be scavenged from a directed beam of RF energy.

[0074] The scavenged energy is stored temporarily in an energy storage device because both supply and demand of energy may vary. For example, when an indoor photo-voltaic is used, no energy may be extracted during the night when the lights are off. The smoke detector used in the WSN can also be operated in duty cycles. An internal clock wakes up the controller from standby mode periodically (e.g. every few seconds to a few tens of seconds). Upon waking up the controller will switch on the

light source of the smoke detector and subsequently read its differential signal and the temperature sensor for a short period of time. The controller will determine whether smoke is present. If smoke is detected it will use the radio to send out a message containing that information.

[0075] The energy storage device may be a rechargeable battery or a (super) capacitor. This storage device may be a separate device located near the silicon die or integrated within the silicon die.

[0076] The different sensing elements (some sensors, temperature sensor, ...) generally convert physical or chemical properties into electrical signals. Also signal conditioning is considered to be part of the sensing element. The controller (e.g. a microcontroller) digitizes the data from the sensing elements, and may perform some processing (cross-correlation, calibration, etc) and packages the data thus obtained in messages. The radio is used to transmit the data to other nodes in the sensor & actuator network. Optionally, the WSN may be able to receive radio messages, such as acknowledgements or configuration messages.

[0077] In another embodiment, the smoke detector may be integrated in mobile phones or Personal Digital Assistants (PDAs) for personal fire warning. Using the mobile phone communication the smoke alarm signal can also be sent out to an emergency center or simply just triggers a sound alarm to warn the owner of the device.

[0078] By using a reflector to fold the optical path, and an integrated construction, the smoke detector of the invention has a small form-factor, low-power and low-cost.

[0079] The use of the differential signal mode and the extra temperature sensor helps increase the accuracy of the detection and reduce the risk of false alarm.

[0080] The smoke detector can be used in ultra low power wireless sensor network. Since the power budget of the system in this case is very low and the size is preferably small, the low-power feature and small form-factor of this detector are clearly advantages over conventional smoke detectors.

[0081] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. A smoke detection system, comprising:

- a housing (38);
 a light source (32);
 an integrated circuit (30) comprising an optical detector (D), wherein the light source and the integrated circuit together comprise a detector assembly mounted inside the housing;
 a reflector (34) mounted inside the housing opposite to the detector assembly and to which the light source output is directed; and
 a processor (30) for deriving a signal indicating the presence of smoke in the cavity based on the change of light reception by the optical detector (D).
2. A system as claimed in claim 1, wherein the light source comprises an LED die (32).
3. A system as claimed in claim 2, wherein the LED die (32) is mounted over the integrated circuit (30), or the LED is mounted to the side of the integrated circuit over a common lead-frame.
4. A system as claimed in claim 1, wherein the light source is a part of the integrated circuit (30).
5. A system as claimed in any preceding claim, wherein the optical detector (D) comprises a detector laterally spaced from the reflected path of the light source output when the cavity is clear of light scattering material.
6. A system as claimed in claim 5, wherein the processor is adapted to determine apply a threshold to the detector signal to derive the signal indicating the presence of smoke.
7. A system as claimed in any one of claims 1 to 4, wherein the optical detector (D) comprises a first detector in the reflected path of the light source output when the cavity is clear of light scattering material, and a second detector laterally spaced from the reflected path of the light source output when the cavity is clear of light scattering material.
8. A system as claimed in claim 7, wherein the processor is adapted to determine a difference between the first and second detector signals and derive the signal indicating the presence of smoke from the difference signal.
9. A system as claimed in any one of claims 5 to 8, wherein the or each detector comprises a photodiode or photodiode array.
10. A system as claimed in any preceding claim, wherein the integrated circuit further comprises a temperature sensor.
11. A system as claimed in claim 10, wherein the processor is adapted to use the temperature sensor output to compensate for temperature dependence of the optical detector signals.
12. A system as claimed in any preceding claim, further comprising a radio frequency transmission system for sending a wireless smoke detection message.
13. A system as claimed in any preceding claim, further comprising an energy scavenging unit and an energy store.
14. A system as claimed in any preceding claim, formed as a wireless sensor node.

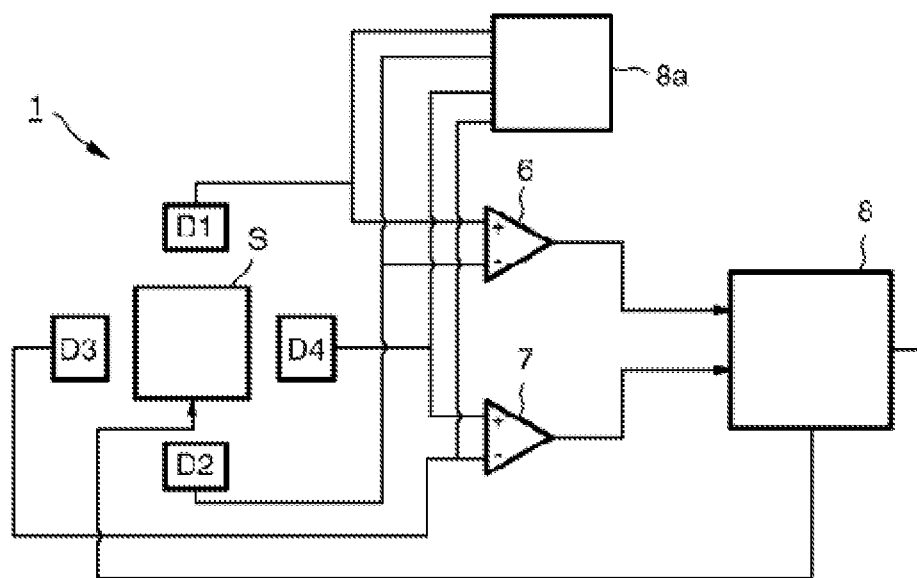


FIG. 1

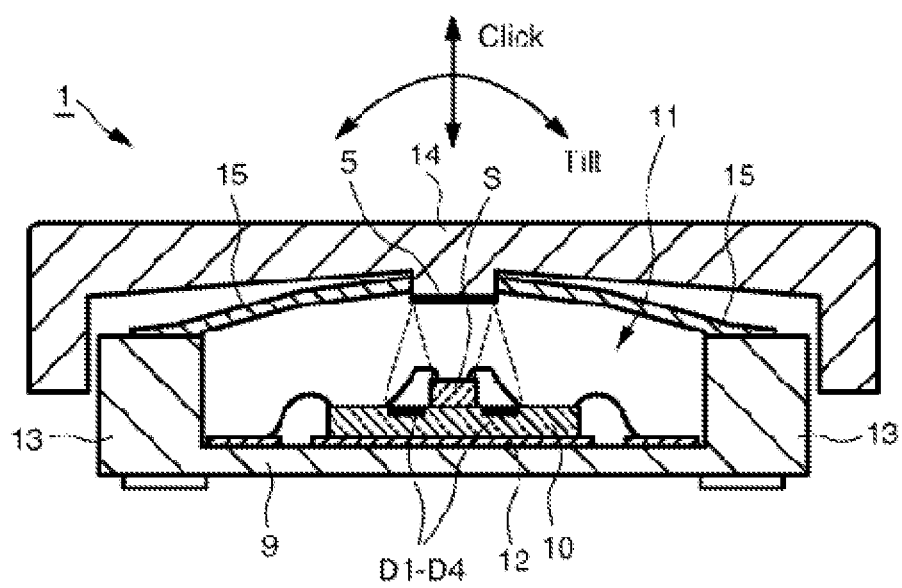


FIG. 2

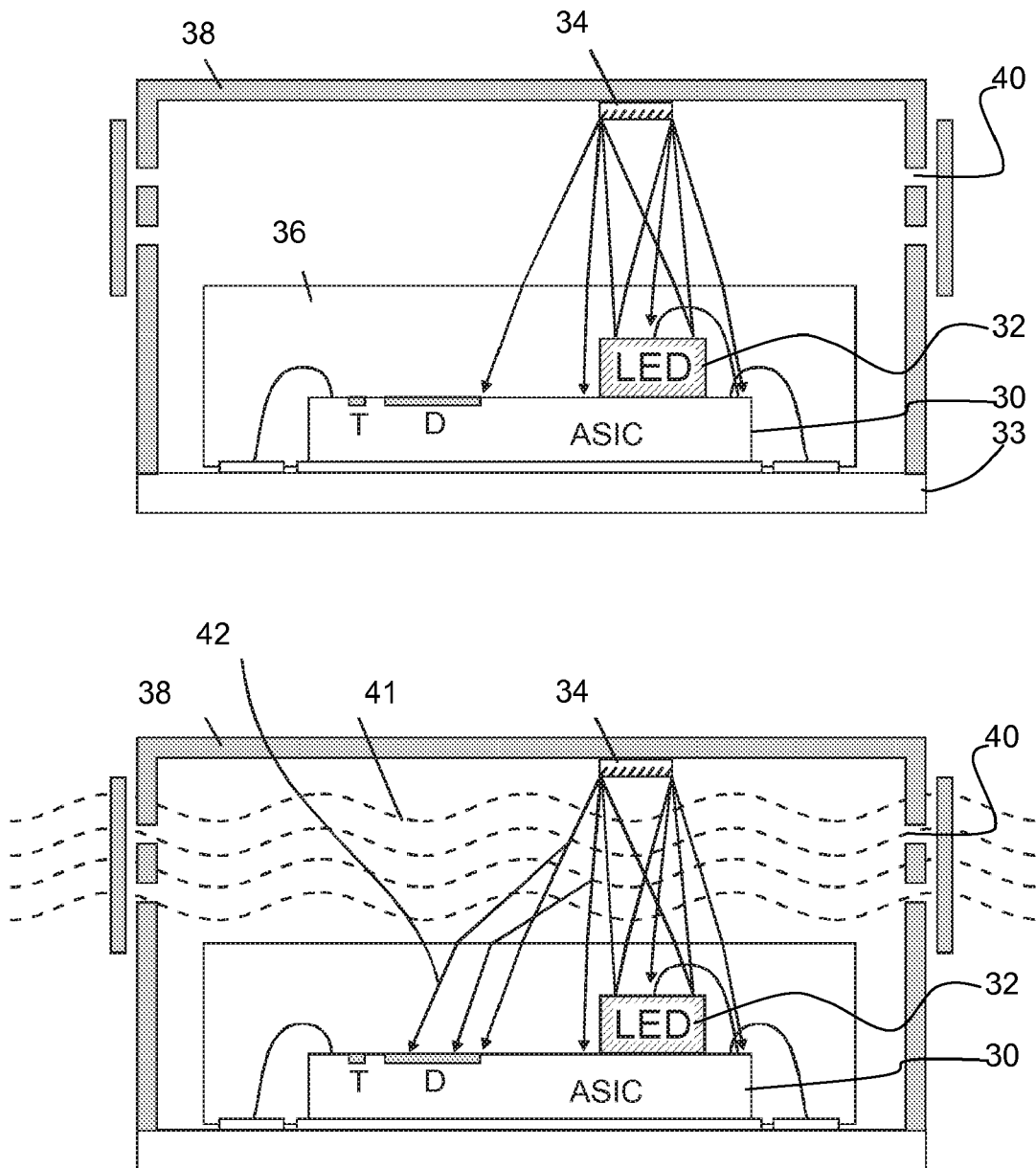


FIG. 3

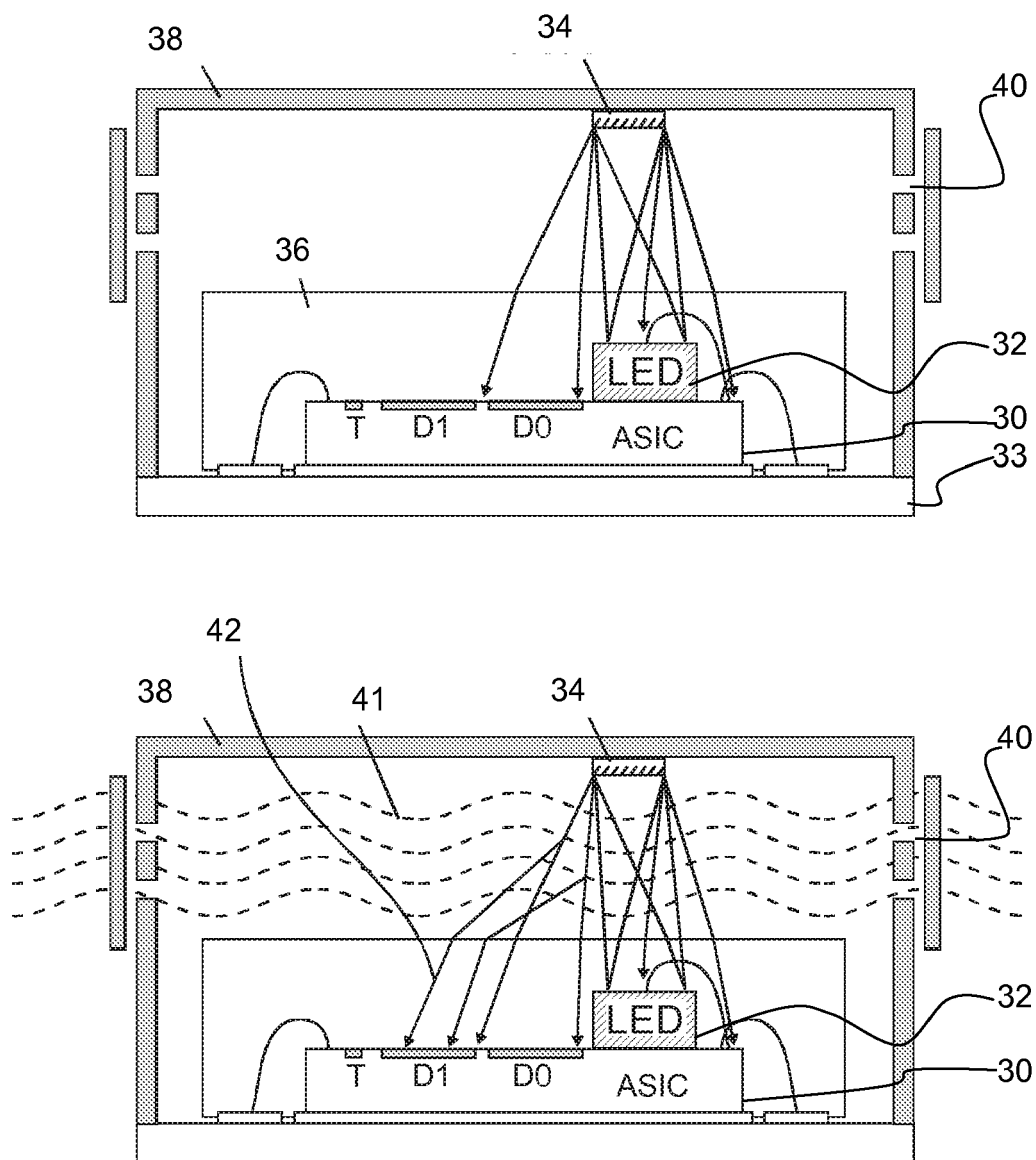


FIG. 4

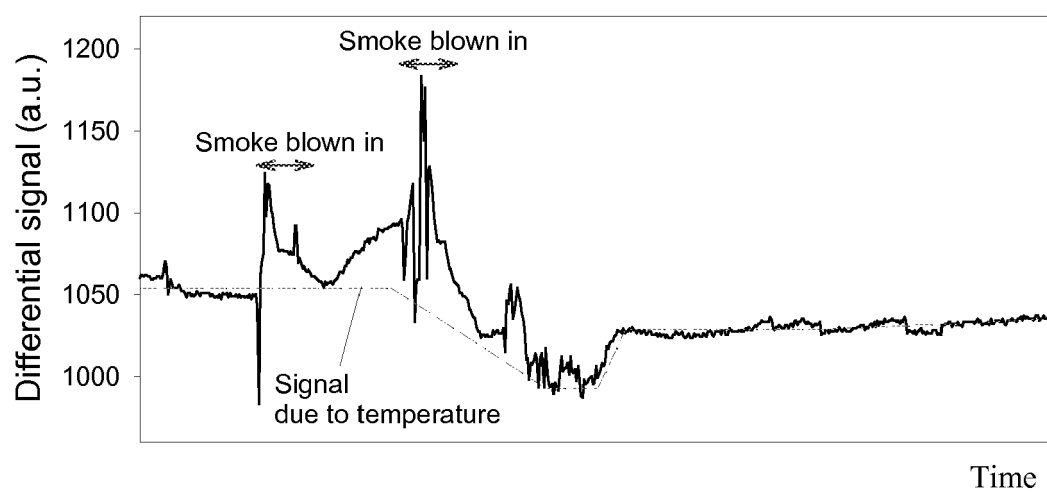


FIG. 5

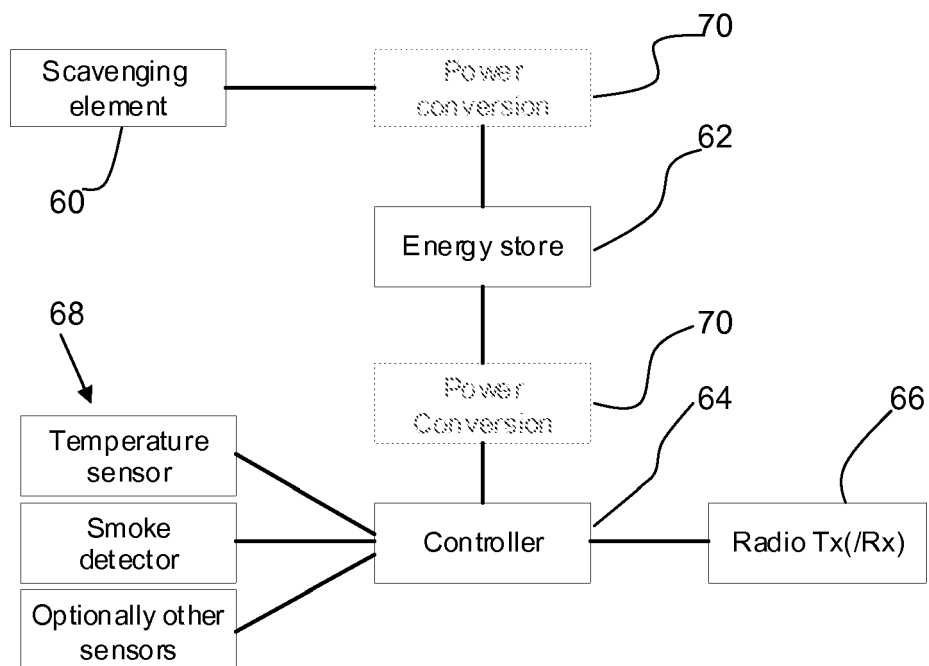


FIG. 6



EUROPEAN SEARCH REPORT

Application Number
EP 10 19 4401

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2002/190232 A1 (CHASON MARC KENNETH [US]) 19 December 2002 (2002-12-19)	1-6,9	INV. G08B17/107
Y	* paragraph [0096] * * paragraph [0121] * * paragraph [0125] * * paragraph [0127] * * paragraph [0131] - paragraph [0133] *	7,8, 10-14	
A	JP 2005 164444 A (NIPPON KOGAKU KK) 23 June 2005 (2005-06-23) * the whole document * * paragraph [0030] *	1-14	
A	DE 10 2004 023524 B3 (JOB LIZENZ GMBH & CO KG [DE]) 15 September 2005 (2005-09-15) * paragraph [0021] - paragraph [0023] * * paragraph [0017] *	1,4-6, 10,11	
Y	WO 02/089082 A1 (GENTEX CORP [US]) 7 November 2002 (2002-11-07) * page 10, line 14 - page 11, line 11 * * page 6, lines 12-23 * * page 30, lines 12-15 * * page 3, lines 3-5 * * page 10, lines 1-5 * * page 12, last paragraph *	10,11	
Y	US 4 021 792 A (LUDT ROY R ET AL) 3 May 1977 (1977-05-03) * column 5, lines 24-47 * * column 8, line 64 - column 9, line 10 *	7,8	
Y	JP 2006 268132 A (TEMPEARL INDUSTRIAL) 5 October 2006 (2006-10-05) * the whole document *	12-14	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			G08B H01L G01N
3	Place of search The Hague	Date of completion of the search 4 July 2011	Examiner de la Cruz Valera, D
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.02 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
EP 10 19 4401

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 4 857 895 A (KAPRELIAN EDWARD K [US]) 15 August 1989 (1989-08-15) * column 2, lines 41-68 * * column 5, lines 11-41 * -----	1,5-8	
A	EP 2 093 733 A1 (SIEMENS AG [DE]) 26 August 2009 (2009-08-26) * paragraph [0070] - paragraph [0073] * -----	1-14	
A	EP 2 091 029 A1 (SIEMENS AG [DE]) 19 August 2009 (2009-08-19) * paragraph [0013] - paragraph [0016] * -----	10,11	
A	DE 10 2004 055274 A1 (BOSCH GMBH ROBERT [DE]) 18 May 2006 (2006-05-18) * paragraph [0027] * -----	1-14	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
Place of search The Hague		Date of completion of the search 4 July 2011	Examiner de la Cruz Valera, D
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

3

EPO FORM 1503 03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 10 19 4401

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-07-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002190232 A1	19-12-2002	NONE	
JP 2005164444 A	23-06-2005	NONE	
DE 102004023524 B3	15-09-2005	EP 1596349 A1 ES 2270399 T3 US 2005253730 A1	16-11-2005 01-04-2007 17-11-2005
WO 02089082 A1	07-11-2002	CA 2443004 A1 MX PA03009715 A	07-11-2002 29-01-2004
US 4021792 A	03-05-1977	NONE	
JP 2006268132 A	05-10-2006	JP 4619842 B2	26-01-2011
US 4857895 A	15-08-1989	CA 1292533 C	26-11-1991
EP 2093733 A1	26-08-2009	AT 507544 T CN 101952863 A WO 2009103668 A1 US 2011037971 A1	15-05-2011 19-01-2011 27-08-2009 17-02-2011
EP 2091029 A1	19-08-2009	AT 493724 T WO 2009101187 A1	15-01-2011 20-08-2009
DE 102004055274 A1	18-05-2006	NONE	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2010035170 A [0020] [0021]
- WO 2010020906 A [0020]
- WO 2009125360 A [0020]

Non-patent literature cited in the description

- **G. CHEN et al.** A Millimeter-Scale Nearly-Perpetual Sensor System with Stacked Battery and Solar Cells. *Proc. ISSCC*, 2010 [0066]