(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 363 844 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.09.2011 Bulletin 2011/36

(51) Int Cl.:
G08B 17/10 *(2006.01)* ***G08B 29/22*** *(2006.01)*
G08B 29/18 *(2006.01)*

(21) Application number: **11394005.0**

(22) Date of filing: **04.03.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **04.03.2010 IE 20100130**

(71) Applicant: **E.I. Technology Limited**
Shannon,
County Clare (IE)

(72) Inventors:
- **Byrne, Michael**
Limerick (IE)
- **Flynn, Fergus**
Newmarket-on-Fergus
County Clare (IE)
- **Guinee, Michael**
Limerick (IE)
- **Duignan, James**
Limerick (IE)

(74) Representative: **Weldon, Michael James et al**
John A. O'Brien & Associates
Third Floor,
Duncairn House,
14 Carysfort Avenue
Blackrock, Co. Dublin (IE)

(54) **Improvements relating to smoke alarm devices**

(57) A smoke alarm device comprises an optical smoke sensor including a light emitting diode (IRED) and a photo-detector (PD) mounted in a chamber, and a circuit with a processor (U1), a user interface, and a sound emitter (HORN). The processor is adapted to cause the light emitter (IRED) to be pulsed by a drive circuit. The processor (U1) enters a de-sensitized mode for at least a first and a second period upon receipt of user commands. It automatically performs dust compensation re-calibration in the second or a subsequent de-sensitized period. The re-calibration is implemented in a duration of less than twenty minutes. Also, the processor directs emission of an indicator that the device is de-sensitized while it is in the de-sensitized mode. The processor ceases alarming for a period in excess of 4 hours if it performs dust compensation and also receives a hush instruction from a user. The circuit includes a current source for the light emitter to maintain a uniform current through said emitter. The current source comprises a light emitter control switch transistor (Q3) in series with the light emitter, a resistor (R25) connected between the light emitter switch (Q3) and ground, a diode (U3) providing a voltage reference for a base of a light emitter switch (Q3), and a control switch (QP2) linked with the base of the light emitter switch (Q3), and means in the processor (U1) for activating the control switch (QP2).

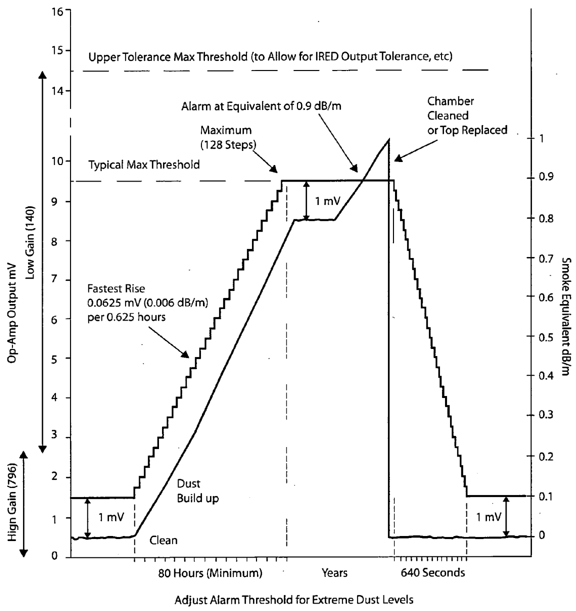

Fig.5

EP 2 363 844 A1

Description

Introduction

[0001] The invention relates to smoke alarm devices.

[0002] For many years most smoke alarm devices were powered from 9 Volt circuits. Due to the combined pressures for smaller physical size, greater reliability, extended longevity and cost there has been a trend in recent years towards smoke alarms operating from a single 3 Volt lithium cell which is capable of powering the device for over 10 years.

[0003] Using a single 3 Volt cell presents a number of challenges as the device must operate satisfactorily from about 3.6 Volts down to about 2.2 Volts (this is the typical operating range of low voltage microcontrollers).

Stable Smoke sensitivity over Voltage range

[0004] A challenge is keeping the smoke sensitivity reasonably constant over the battery range. This implies keeping a constant current in the infra red diode (IRED) for measuring the smoke in the sensing chamber. For example, with an IRED forward voltage of 1.6 Volts there is very little "head room" to control this current at the lower operating voltage of 2.2 Volts.

Wide dynamic range for good stability and dust compensation

[0005] Another challenge with the known smoke sensing circuitry is having a wide dynamic range as the circuit needs to be able to measure the voltage across the photodiode for the various conditions such as the following:

	Photodiode Voltage
Standby (IRED photons reflected off black walls)	0.5 mV
With 0.1 dB/m smoke	1.5 mV
With 0.5 dB/m smoke/at hush level	5.5 mV
With smoke of 0.1 dB/m and high dust compensation	9.5 mV

[0006] In addition, there can be a wide spread in the brightness of the IREDs (i.e. photon output per milliamp drive current) of typically +/- 50% from the above typical figures. In this example, this means that the circuit must be able to measure from 0.25mV to 14.25mV - a range ratio of 57 (i.e. 14.25/0.25 = 57).

Temperature Stabilised Smoke Sensitivity

[0007] The circuit must also allow for variations in the IRED output with temperature. Typically the IRED temperature coefficient is - 0.8% per degree C. Uncorrected, this can allow for undesirable changes in smoke sensitivity over the operating temperature range of say-10°C to 55°C.

Reduced sounder current spikes

[0008] The sounder must produce 85dB(A) at 3 metres according to a common standard. A typical piezoelectric disc sounder requires over 15 Volts peak to peak to achieve this. Designers commonly use a ringing choke (with step-up turns) approach. This will typically draw peak currents of about 40mA. It is important to keep this as low as possible, so as to minimise the load on the lithium cell and so reduce its output voltage drop as it supplies this current, particularly at low temperatures such as 0°C. If the cell voltage drops below 2.2 Volts, the devices can stop operating, reset, or in the worst case latch up (for example if the microcontroller clock stops) with the horn and/or LEDs on.

[0009] A key drawback of a ringing choke circuit is that it can draw a pulse of current over twice the normal run current (i.e. about 90mA) on start up for about 1 millisec.

Contamination

[0010] A major problem with many known optical smoke alarms is that eventually many of them become contaminated and go into continuous alarm as the whitish dust on the black inside walls of the sensing chamber scatter the light in a similar fashion to smoke. At present, these would have to be taken down and the power disconnected for them to be silenced. This requires the user to get a step ladder or similar and this can be a nuisance, particularly during the night and also dangerous for people such as the elderly. Our prior European patent specification number EP 1098284 describes an approach in which sensitivity is increased or decreased in response to dust build-up or subsequent cleaning.

[0011] The invention is directed towards providing an improved smoke alarm device of the optical type, in which some or all of the above problems are addressed.

Summary of the Invention

[0012] According to the invention, there is provided a smoke alarm device comprising:

an optical smoke sensor including a light emitting diode and a photo-detector mounted in a chamber,
a circuit with a processor, a user interface, and a sound emitter, in which the processor is adapted to cause the light emitter to be pulsed by a drive circuit, and
wherein the processor is adapted to enter a de-sensitized mode for at least a first and a second period upon receipt of user commands, and the processor is adapted to automatically perform dust compensation re-calibration in said second or a subsequent de-sensitized period, wherein the re-calibration is implemented in a duration of less than twenty minutes, wherein the processor directs emission of an indicator that the device is de-sensitized while it is in the de-sensitized mode.

[0013] In one embodiment, the processor is adapted to cease alarming for a period in excess of 4 hours if it performs dust compensation and also receives a hush instruction from a user.

[0014] In one embodiment, the circuit includes a current source for the light emitter to maintain a uniform current through said emitter, wherein said current source comprises a light emitter control switch transistor in series with the light emitter, a resistor connected between the light emitter switch and ground, a diode providing a voltage reference for a base of a light emitter switch, and a control switch linked with the base of the light emitter switch, and means in the processor for activating the control switch.

[0015] In one embodiment, the circuit includes gain components for providing different gains from the light detector, and the processor is adapted to choose an appropriate gain, wherein the gain components include a plurality of inter-connected op-amps, in which a capacitance across the gain-setting resistor of an op-amp provides attenuation of high frequency noise and a capacitance in series between two op-amps provides filtering of DC and low frequency noise caused by ambient light.

[0016] In one embodiment, the processor is adapted to dynamically choose a gain value according to temperature-induced variations in light output of the light emitter.

[0017] In one embodiment, the gain stage components include four op-amps arranged to amplify the detector output, in which a full gain is provided by the four stages and a lower gain is provided by the first three stages, and in which the processor is adapted to use the high gain until the photo-detector output signal is just below the supply and to then switch over to the low gain to ensure that the lowest signal to be amplified has an output from the high gain stages which is large enough to give an target signal to noise ratio for both internally-generated noise and externally-generated noise.

[0018] In one embodiment, the circuit is adapted to compensate for a reduction of light emitter photon output as temperature increases, in which the circuit comprises a first clock having a low temperature variation but high power consumption, and a watchdog timer which has a higher temperature variation but low power consumption, and the processor is adapted to normally use the watchdog timer and to switch to use of the first clock periodically to measure the period of the watchdog timer to deduce the temperature from the change in this period.

[0019] In one embodiment, the sound emitter includes a piezoelectric membrane, and the processor is adapted to interrupt a drive to the sound emitter at start-up, wherein the drive is interrupted for a time duration of approximately the period of the piezo membrane.

[0020] In one embodiment, the processor is adapted to speed up a light emitter activation rate in response to increased smoke detection.

[0021] In one embodiment, the processor is adapted to trigger a next shorter inter-activation duration upon smoke level reaching successively higher thresholds until an alarm level is reached.

[0022] In one embodiment, the processor is adapted to generate an output for identifying the device from within a group of devices, in which the processor is adapted to turn on a combination of a sound emitter and two flashing indicators to indicate a low battery or fault, or a contaminated chamber, or if the device had been in alarm previously in response to user pressing of a test button, wherein said time period is in the range of 0.2 seconds to about 0.75 seconds between flashes.

[0023] In one embodiment, the processor is adapted to identify if the device is approaching a low battery condition or a dust contaminated condition, and to generate an output indicating this, in which the processor is adapted to generate said output if it is projected that the condition will arise in a time period of 6 to 24 months, preferably 12 to 18 months.

[0024] In one embodiment, said output is generated in response to user pressing of a test button.

[0025] In one embodiment, the processor is adapted to apply a more stringent battery test to determine if the device is approaching a low battery condition.

[0026] In one embodiment, said test is performed only during a user interaction such as at a button test, thus helping to avoid the problem of a premature indication caused by low temperature.

Detailed Description of the Invention

[0027] The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only with reference to the accompanying drawings in which:-

Figs. 1 to 4 are diagrams illustrating a circuit of a smoke alarm device of the invention;

Fig. 5 is a plot of op-amp output vs. time illustrating response of the device to various dust conditions; and

Fig. 6 is a table illustrating parameters for operation of the device.

[0028] Referring to Figs. 1 to 4 a circuit of a smoke alarm device of the invention comprises a microcontroller U1 (Fig. 2), a smoke sensing chamber with a light emitting diode IRED (Fig. 2) and a photo detector PD (Figl), a 3V lithium cell (Fig. 4), a piezoelectric horn HORN (Fig. 4) and LED indicators LED 1 and LED 2 (Fig. 4).

[0029] Additionally:

Fig. 1 shows a gain control circuit U2 which is powered just as required by the collector of the PNP transistor in QP1 to minimise battery drain.

Fig. 2 shows the processor U1 and a control circuit including transistors QP2 and Q3 and various other components for driving the IRED in a uniform manner.

Fig. 3 shows interconnect circuitry, in which an interconnect terminal is sensed by transistor QP7 for an incoming signal, and driven directly by the microcontroller U1 to provide an outgoing signal.

Fig. 4 shows the 3V cell, drivers for indicating yellow and red LEDs YLW_LED and RED LED/10_IN, and the horn HORN.

[0030] The main functions programmed into U1 are as follows.

- Driving the light emitter IRED to give a 100 microsecond pulse and measuring the associated amplified signal from the photo diode PD.
- Turning on the horn to give an alarm or fault beeps.
- Turning on the two indicator red and yellow LEDs as appropriate.
- Measuring the battery voltage using the U3 (Fig. 2) precision voltage reference, while loading the battery with a suitable pulse current through R31. U3 is drawn as a zener diode because it behaves similarly to one, but it is not a signal diode, it is a band-gap precision reference. As shown in Fig. 2 it is connected on the line driving the base of Q3.
- Interfacing to the radio frequency module through the RF MODULE (Fig. 3) socket such that when the device senses fire it signals to all the other devices to give an alarm, and vice versa. It also allows remote testing and controlling of the alarm.
- Interconnect signalling to other smoke/heat alarm devices through the hard wire interconnect option (IO+ and IO-) such that if one device senses smoke, all of the devices will alarm.

[0031] Capacitors C1 and C2 as shown give attenuation of high frequency noise (C2) and also filtering of DC and low frequency noise (C1 with resistor R9A) caused by high levels of ambient light, for example from sunshine or 100 Hz light from fluorescent tubes entering the optical chamber. Because C1 and the associated resistor R9A are connected in series between two op-amps it filters the DC and low frequency noise, and because C2 is connected across the gain setting resistor of another op-amp it is very effective at filtering out high frequency noise.

[0032] As shown in Fig. 3 the device also includes an RF module for interconnecting to other alarms and for user remote control.

[0033] A further feature of the invention is to give fast response to fires but at the same time to keep the current drawn from the battery to a minimum. Pulsing the IRED with the high current needed (typically 250 mA or higher) is a major part of the drain on the battery.

[0034] The IRED is pulsed every 16 seconds. This would therefore be expected to have a response time of between 3 and 19 seconds. The 19 seconds can be too long in some circumstances and to overcome this, the IRED pulsing is speeded up as the smoke increases in the chamber as follows. This ensures that during fire tests, in which the smoke builds up in times of the order of less than 60 seconds, the device responds rapidly. This can be very beneficial in a critical fire situation. It is also beneficial in comparison fire tests between competitive smoke alarms.

Smoke Level	IRED Pulse Rate
dB/m	Seconds
0.0	16
0.025	8
0.050	2
0.075	1
0.100	1 (alarm level)

[0035] The device addresses the problem of achieving stable smoke sensitivity over the voltage range as follows.

[0036] The IC U2 is a quad operational amplifier (op-amp) and is used to amplify the low level voltage signal from the photodiode PD (bottom right corner of Fig 1). There are four op-amps as illustrated, the gain values of which are included in Fig. 1. The op-amps step up the voltage from one to the other, conditioning the voltage for U1, particularly for analogue-to-digital conversion. U2 provides two outputs as shown in the top left corner of Fig. 1, namely O/P 1 and O/P 2. The gains for these two outputs are 796 and 140.

[0037] The quad op-amp U2 amplifies the photodiode (PD) signal. The full gain of the four stages is 796 and the lower gain of the first three stages is 140. The microcontroller uses the high gain until the output signal is just below the supply. It then switches over to the low gain. This ensures that the lowest signal to be amplified, typically 0.25mV, will have an output from the high gain stages of (796 x 0.25mV) = 0.199 Volts. This signal is large enough to give an adequate signal to noise ratio for both internally generated noise and externally generated noise. At the other extreme, the 14.25mV when amplified by 140 gives a signal of 1.99 Volts which is below lowest supply voltage. These gains allow the use of low cost 8-bit A-to-D conversion as the above voltages give sufficient digital bits / resolution for the accuracy required for the calculations.

[0038] Referring to Fig. 2, the circuit addresses the problem of varying battery voltage (3.6V down to 2.2V) causing differing light output from the IRED. The band gap precision voltage reference U3, (Fig 2) provides a stable voltage level Vref of 1.22V at the base of Q3. The capacitor C14 stores the battery voltage. The microcontroller U1, using pin 3 turns on the PNP transistor in QP2 which in turn biases on the voltage reference U3 which generates Vref (1.22 Volts) at the base of the IRED driver transistor Q3. This is configured as a current source as the voltage on its emitter is V_{ref} - V_{be} = 0.52 Volts, and the resistor R25 sets the current (typically (0.52 / 1.8 = 288mA). The current in the IRED will remain stable to V_{dd} = 2.2 Volts as long as the forward voltage across the IRED is less than 2.2 - 0.52 - 0.05 = 1.63 Volt.

[0039] Regarding the problem of temperature sensitivity, the circuit configuration has the added benefit that is gives an inherent temperature compensation of close to - 0.8% per degree C to overcome the reduction in the photon output of the IRED as the temperature increases (and vice versa).

[0040] If this compensation needs to be increased, then the temperature can be deduced using just the microcontroller without any additional components as follows. The internal microcontroller circuit has two clocks. There is a 4MHz clock with a tolerance of 2% which has little temperature variation and draws 0.5mA. This is only turned on as needed to minimize power utilisation and hence prolong battery life. The second clock is a watchdog timer which draws less current and is sensitive to temperature variation. The processor U1 is programmed to normally use the watchdog timer and to switch to use of the first clock periodically to measure the period of the watchdog timer to deduce the temperature from the change in this period. If extra temperature compensation is needed, then the output voltage from the op-amps is multiplied by an appropriate constant to allow for this, prior to further analysis of the smoke chamber signal.

[0041] Regarding the problem of sounder current spikes, the problem with the large piezo current pulse on start-up is solved by the microcontroller turning on the transistor Q1 for about 300 microseconds (approximately the period of the piezo disc, which has a nominal resonant frequency of 3000Hz). It then interrupts the drive to Q1 for about 150 microseconds and then turns the drive on continuously thereafter.

[0042] This has the effect of the piezo disc getting its oscillations going more quickly and, importantly, producing a feedback signal which turns off Q2 in about 600 microseconds (this is much less than the 1000 microseconds which it takes if Q1 is not pulsed as described). This has the result that the current pulse on start-up is only about 10% over the normal run current whereas without the pulse it is about twice the normal run current.

[0043] Fig. 5 shows the very high level of dust compensation that the invention allows i.e. it can tolerate 8 times the level of dust that would cause an uncompensated device to give an alarm. On the other hand a dust compensation of just 2 or 3 are typical of the present state of the prior art.

[0044] The following is the manner in which the device deals with the problems of nuisance alarms from activity such as cooking and also from dust build-up in the optical chamber. The user presses the test/hush button and the device is de-sensitised for 10 minutes. If the smoke clears the device will not go back into alarm and the "problem" is solved.

However, if the device goes back into alarm, pressing the test/hush button (within 4 minutes) will again de-sensitise the device for 10 minutes, but now towards the end of this second ten minutes, the device will "quickly" compensate for the contamination in the chamber within a few minutes. In standby this normally takes hours, to ensure it does not inadvertently compensate for a slowly developing fire.

[0045] If the smoke alarm does not go back into alarm, the dust compensation algorithm has now fixed the problem and the issue is resolved.

[0046] However, if the device goes back into alarm for the third time (i.e. the device has now been seeing an alarm condition for over (10 + 10 =) 20 minutes, the user presses the hush/test button (within 4 minutes of it going back into alarm) for a third time. Now the smoke alarm silences the horn for 8 hours, (provided the chamber continues to sense an alarm condition). If the alarm condition clears (e.g. due to the chamber being cleaned) for at least 5 minutes continuously (to ensure the alarm is not being caused by "intermittent" contamination such as a fibre wafting in and out of the sensitive part of the chamber) then the smoke alarm goes back to normal standby. During the 8 hours the device will give two short beeps (10 millisec long) about 0.5 seconds apart every 10 minutes to gently remind the user that the device is not operational and should be replaced. This also allows it to comply with the standard EN14604 alarm silence facility clause that states "continuous operation of the alarm silence control shall not lead to the smoke alarm being de-sensitised for more than 15 minutes without an audible warning being given".

[0047] After the 8 hours the device will go back into its alarm and now pressing the test/hush button (within 4 minutes) will silence it as in 3 above for a further 24 hours (with 2 beeps every 10 minutes). If the smoke chamber contamination is cleaned the device will reset to normal sensitivity.

[0048] There has rightly been a great reluctance to allowing users to "permanently" disable a smoke alarm. However the above does not allow the user to disable the horn, and keep it disabled, unless the following stringent conditions are fulfilled:

- until it has been in alarm over 20 minutes
- the hush button has to be pressed three times, at 10 minute intervals
- the device will return to normal sensitivity if the "permanent" alarm condition clears
- there is an audible and visual warning of two beeps every 10 minutes to inform the user the device is not capable of sensing smoke.

[0049] If a device has been in alarm for over 20 minutes and there is no smoke, the user is going to silence it one way or the other (e.g. by pulling it off the ceiling and possibly damaging both the ceiling and the device) - as by this stage the smoke alarm is just giving a useless and very noisy nuisance alarm.

[0050] When a device is contaminated and in continuous alarm, it is essentially of no further use to the resident as a smoke alarm. It is reasonable therefore to give the user 8 hour respite from the horn sounding by just pressing the button, in a defined sequence, to prevent inadvertent use.

[0051] In a further embodiment the hush could be enabled by remotely using a hardwired switch or by using a radiolink switch.

[0052] Some standards allow radio transmitting devices to automatically silence the horns once the alarm has been given for at least 30 minutes. This is to preserve battery life and is based on the premise that users will have taken appropriate action (e.g. by evacuating the premises or by extinguishing the fire) well before the 30 minutes of alarm has elapsed.

Simple Maintenance Diagnostic Tests

[0053] In recent times more and more smoke alarms are being tested/inspected and monitored at least yearly by trained personnel (for example this is becoming mandatory in some countries). At present many inspectors simply wipe the smoke alarm with a damp cloth, to remove any external dust or cobwebs and press the test button. This tells the inspector that the device is working at present, but does not give any indication of imminent or intermittent problems such as build-up of contamination, of the battery nearing depletion or of poor location.

[0054] A further problem is that if a device (in say a property with 10 alarms) is giving beeps just once a minute it can be very tedious and time-consuming to locate it, and indeed some inspectors in a hurry might replace all the devices rather than spend the time to identify the problem device. Some manufacturers have test apparatus for field engineers for testing devices after they have been removed from the ceiling. This is effective but costly as the devices have to be removed from the ceiling and special unique apparatus for each type of alarm is required.

[0055] The controller U1 is programmed to give the inspector, using simple indicators already in the alarm, comprehensive data to allow them to quickly identify defective devices and also devices that are likely to become defective prior to the next inspection period (normally inspections are done annually). The main defects which need to be identified are a partially contaminated device, devices where the battery voltage is close to the low battery trip point and badly sited alarms giving nuisance alarms due to being too close to a kitchen or bathroom.

[0056] Referring to Fig. 6 the inspector presses the test button and the information in the trouble shooting diagnostics section giving the state of the alarm. This also checks if the device is going to give low battery beeps or chamber beeps within about 12 to 18 months.

Indicators and their Uses

[0057] The device of the invention in various embodiments has a comprehensive set of indicators (sounder, red LED and yellow LED) to help the user gain the maximum benefit from the alarms with no, or minimal nuisance effects (such as horn beeps or LED flashes). These are explained below as a set out in the user instructions.

Normal Operation

[0058] In normal operation, the device is silent and there are no LED flashes (which could be intrusive in a dark bedroom at night). The user should press the test button weekly to check the sensor, electronics and horn; and also to familiarise the occupants with the sound of the alarms. The horn will start softly so as to reduce exposure to excessive noise levels.

If a Fire Occurs

[0059] As soon as the device senses smoke it will go into alarm (along with any interconnected alarms). The red LED on the devices sensing smoke flashes rapidly (every ½ second) to indicate if it is the device sensing fire.

If a Nuisance Alarm Occurs

[0060] The user presses the large test button (e.g. with a broom handle) to silence the device for 10 minutes - the red LED will then flash every 8 seconds for 10 minutes while the smoke sensitivity is reduced.

If the Battery is Low

[0061] Normally the battery will last over 10 years before it becomes partially depleted. When electronic self testing indicates that the battery is becoming low the device will beep and the red LED will flash at the same time (about every 32 seconds) to warn the user. This indicates that the device must be replaced. If it is not convenient to replace the device immediately, then the user can press the test button to silence the low battery beeps and stop the red LED flashing for 12 hours. This can be repeated as required.

Contaminated Chamber False Alarm

[0062] If the device goes into alarm without any apparent smoke being present, press the test button to silence the alarm for 10 minutes (as described above). If the device goes back into alarm it may be contaminated. Pressing the test button again, within 4 minutes of the alarm going back into alarm, will get the device to compensate for chamber contamination. This will normally resolve the problem.

[0063] If the device goes into alarm for a third time, the device is excessively contaminated and must be replaced. If it is not convenient to replace it immediately, pressing the test button within 4 minutes of it going into alarm (for the third time) will silence the device for 12 hours - however it will give two short beeps (½ second apart) every 10 minutes to remind the user it has been disabled. If the contamination clears the device will return to normal operation.

[0064] This does not reduce the user's fire protection, as when a device is in continuous alarm due to a fault, it is now useless and must be silenced - by taking the device down or as described here. This procedure has the added benefits that the user is reminded every 10 minutes by two short beeps that the alarm needs to be replaced and that if the problem clears the device will return to detecting fire.

[0065] Pressing the test button after the 12 hours are up and the unit has gone back into alarm, will silence it again for a further 12 hours.

If the Smoke Sensor becomes Defective

[0066] In the unlikely event of the smoke sensing chamber becoming defective, the device will give a short beep with a yellow LED flash every 32 seconds. The device must then be replaced. If it is not convenient to replace it immediately, pressing the test button will silence the beeps and stop the yellow LED flashing for 12 hours. This can be repeated as required.

How to identify which device has been in alarm (memory)

[0067] Sometimes a device may alarm for a short period (e.g. due to a small puff of cooking fumes or vapour from a bathroom). While the horn is sounding the red LED will flashing every ½ seconds. When the horn stops the red LED will give two short flashes (0.5 seconds apart) every 16 seconds for 24 hours. This can be particularly beneficial in identifying a device that gave a short alarm during the night.
[0068] After the 24 hours has elapsed, a device that has been in alarm can still be identified. When the test button is pressed, the horn will sound with rapid chirping (instead of its normal sound). This can be invaluable to a maintenance person troubleshooting a property some days, or even months later - as it can highlight that a particular device should be moved further from a kitchen or bathroom or that a particular device has an intermittent defect. This pressing of the test button also resets the two memory features.

How to identify which device is giving fault beeps

[0069] If one smoke alarm is giving short beeps every 32 seconds and there are a number of devices in the house, then the one giving the beeps can be quickly identified by simply pressing the test button.
[0070] There are two possibilities when the button is pressed:

amber LED flashes every 0.5 seconds and horn sounds:

low battery, replace device,

amber LED flashes every 0.5 seconds but horn does not sound:

chamber defective, replace device.

How to Identify Heavily Contaminated Alarms

[0071] Press the test button and if the device is heavily contaminated the red and amber LEDs will flash alternatively every half second - the horn will ramp up the sound in the normal way. (This red / amber / red / amber indication on pressing the button is also given when the device is likely to false alarm continuously within about 18 months, assuming the contamination continues build-up continues. It also gives this indication if it already is giving a continuous false alarm but it has been silenced for 12 hours as described in 5 above).
[0072] How to identify if a device should be replaced:

Check the "replace by date" on the sidewall.

[0073] Press the test button and check the horn ramps up to full sound and the red LED flashes every 0.5 seconds. If this does not occur, replace the device.
[0074] When the test button is pressed the low battery voltage trip point is increased, by the expected voltage drop over the following year (typically by 40 mV to 100 mV) and if the battery voltage is less than this more severe requirement when the test button is pressed, the horn will sound in the normal way but the yellow light will flash rapidly to indicate the battery is likely to give low battery beeps within a year. This allows the inspector to replace the alarm. The user will therefore not be disturbed by beeps during the following year and also the service company will not be called out to replace the device.
[0075] The following is a summary of advantages of the invention:

Suppression of contaminated chamber false alarms for 8 hours in a simple way - units with clean (or cleaned chambers) cannot be de-sensitised for 8 hours.

[0076] Comprehensive diagnostics using just a red LED, a yellow LED, the sounder and the test button to identify:

- which unit had been in alarm in previous 24 hours and/or since button was pressed,
- a unit giving low battery beeps or going to give low battery beeps in 12/18 months,
- a unit giving faulty chamber beeps, and
- a contaminated chamber unit that is likely to become fully contaminated in 12/18 months.

[0077] Faster response to fire as the smoke chamber sampling rate is increased as the smoke builds up from every 16 seconds to 1 second - without significantly increasing current drain on the battery.
[0078] Very high levels of dust compensation (up to 8 times the normal smoke sensitivity) due to the wide dynamic range of the conditioning circuitry, with a just 2.2 volt supply.
[0079] Smoke sensitivity constant over full battery voltage range from 3.6 to 2.2 Volts.
[0080] Horn start up pulse (inductive) significantly reduced by inducing the oscillator to reach the resonant frequency more quickly.
[0081] Smoke sensitivity constant over the full temperature range of -10°C to + 55°C
[0082] It will be appreciated that the invention also provides a simple way of identifying if a device is significantly contaminated and likely to go into continuous alarm within 12 to 18 months by pressing the test button. It also provides a simple way if identifying if the device has been silenced for 12 hours due to a contamination nuisance alarm by pressing the test button. A further advantageous aspect is flashing the LED and the change in the horn sound on button test to find devices that have been in alarm.
[0083] The invention is not limited to the embodiments described but may be varied in construction and detail.

Claims

1. A smoke alarm device comprising:

    an optical smoke sensor including a light emitting diode (IRED) and a photo-detector (PD) mounted in a chamber, a circuit with a processor (U1), a user interface, and a sound emitter (HORN), in which the processor is adapted to cause the light emitter (IRED) to be activated by a drive circuit, and
    wherein the processor (U1) is adapted to enter a de-sensitized mode for at least a first and
    a second period upon receipt of user commands, and the processor is adapted to automatically perform dust compensation re-calibration in said second or a subsequent de-sensitized period, wherein the re-calibration is implemented in a duration of less than twenty minutes, wherein the processor directs emission of an indicator that the device is de-sensitized while it is in the de-sensitized mode.

2. A smoke alarm device as claimed in claim 1, wherein the processor is adapted to cease alarming for a period in excess of 4 hours if it performs dust compensation and also receives a hush instruction from a user.

3. A smoke alarm device as claimed in claims 1 or 2, wherein the circuit includes a current source for the light emitter to maintain a uniform current through said emitter, wherein said current source comprises a light emitter control switch transistor (Q3) in series with the light emitter, a resistor (R25) connected between the light emitter switch (Q3) and ground, a diode (U3) providing a voltage reference for a base of a light emitter switch (Q3), and a control switch (QP2) linked with the base of the light emitter switch (Q3), and means in the processor (U1) for activating the control switch (QP2).

4. A smoke alarm device as claimed in any preceding claim, wherein the circuit includes gain components (U2) for providing different gains from the light detector, and the processor is adapted to choose an appropriate gain, wherein the gain components include a plurality of inter-connected op-amps, in which a capacitance (C2) across the gain-setting resistor of an op-amp provides attenuation of high frequency noise (C2) and a capacitance (C1) in series between two op-amps provides filtering of DC and low frequency noise caused by ambient light.

5. A smoke alarm device as claimed in claims 3 or 4, wherein the processor is adapted to dynamically choose a gain value according to temperature-induced variations in light output of the light emitter.

6. A smoke alarm device as claimed in any of claims 3 to 5, wherein the gain stage components (U2) include four op-amps arranged to amplify the detector output, in which a full gain is provided by the four stages and a lower gain is provided by the first three stages, and in which the processor (U1) is adapted to use the high gain until the photo-detector output signal is just below the supply and to then switch over to the low gain to ensure that the lowest signal to be amplified has an output from the high gain stages which is large enough to give an target signal to noise ratio for both internally-generated noise and externally-generated noise.

7. A smoke alarm device as claimed in any preceding claim, wherein the circuit is adapted to compensate for a reduction of light emitter photon output as temperature increases, in which the circuit comprises a first clock having a low temperature variation but high power consumption, and a watchdog timer which has a higher temperature variation

but low power consumption, and the processor is adapted to normally use the watchdog timer and to switch to use of the first clock periodically to measure the period of the watchdog timer to deduce the temperature from the change in this period.

8. A smoke alarm device as claimed in any preceding claim, wherein the sound emitter (HORN) includes a piezoelectric membrane, and the processor (U1) is adapted to interrupt a drive to the sound emitter at start-up, wherein the drive is interrupted for a time duration of approximately the period of the piezo membrane.

9. A smoke alarm device as claimed in any preceding claim, wherein the processor is adapted to speed up a light emitter activation rate in response to increased smoke detection.

10. A smoke alarm device as claimed in claim 9, wherein the processor (U1) is adapted to trigger a next shorter inter-activation duration upon smoke level reaching successively higher thresholds until an alarm level is reached.

11. A smoke alarm device as claimed in any preceding claim, wherein the processor is adapted to generate an output for identifying the device from within a group of devices, in which the processor is adapted to turn on a combination of a sound emitter and two flashing indicators to indicate a low battery or fault, or a contaminated chamber, or if the device had been in alarm previously in response to user pressing of a test button, wherein said time period is in the range of 0.2 seconds to about 0.75 seconds between flashes.

12. A smoke alarm device as claimed in any preceding claim, wherein the processor (U1) is adapted to identify if the device is approaching a low battery condition or a dust contaminated condition, and to generate an output indicating this, in which the processor is adapted to generate said output if it is projected that the condition will arise in a time period of 6 to 24 months, preferably 12 to 18 months.

13. A smoke alarm device as claimed in claim 12, wherein said output is generated in response to user pressing of a test button.

14. A smoke alarm device as claimed in claims 12 or 13, wherein the processor (U1) is adapted to apply a more stringent battery test to determine if the device is approaching a low battery condition.

15. A smoke alarm device as claimed in claim 14, wherein said test is performed only during a user interaction such as a button test, thus helping to avoid a the problem of a premature indication caused by low temperature.

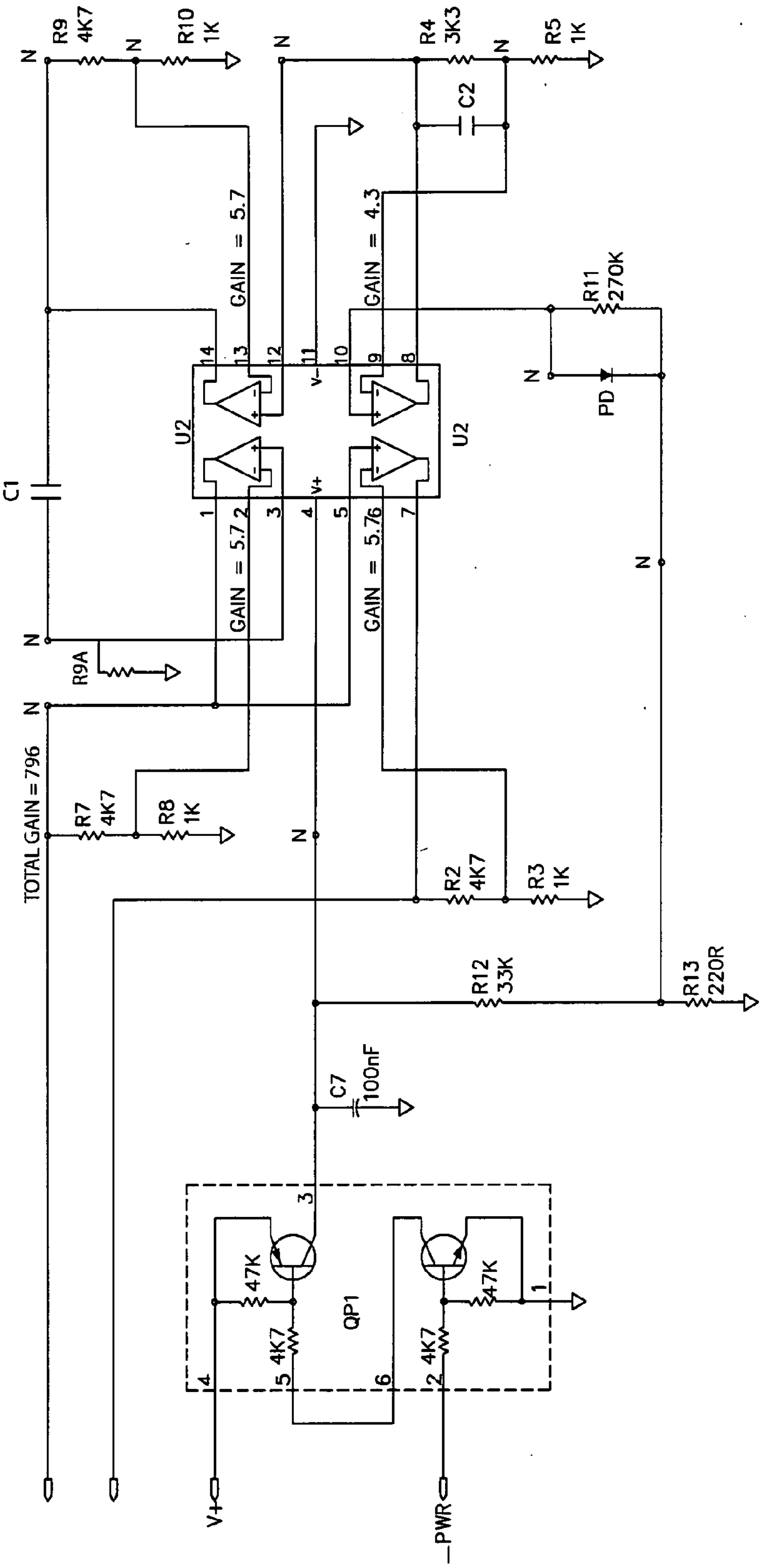
R9
4K7
R10
1K
R4
3K3
R5
1K
C2
C1
GAIN = 5.7
GAIN = 4.3
GAIN = 5.76
U2
R11
270K
PD
R9A
TOTAL GAIN=796
R7
4K7
R8
1K
R2
4K7
R3
1K
R12
33K
R13
220R
C7
100nF
QP1
47K
4K7
V+
PWR

Fig.1

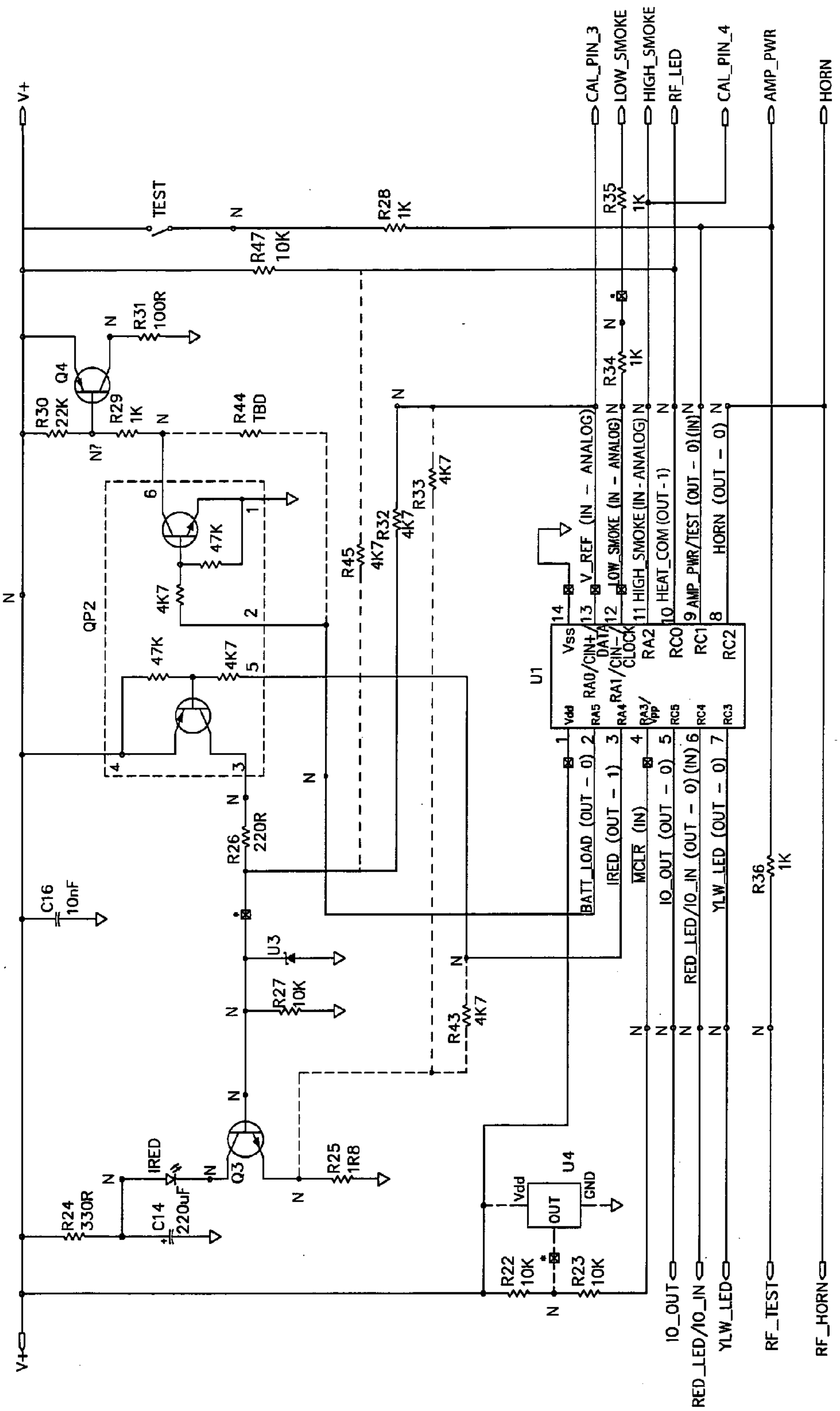
V+
TEST
R28 1K
R47 10K
R35 1K
R34 1K
R31 100R
Q4
R30 22K
R29 1K
N7
R44 TBD
QP2
47K
4K7
R45 4K7
R32 4K7
R33 4K7
U1
Vdd
Vss
RA5
RA4
RA3/VPP
RC5
RC4
RC3
RA0/CIN+ DATA
RA1/CIN- CLOCK
RA2
RC0
RC1
RC2
BATT_LOAD (OUT - 0)
IRED (OUT - 1)
MCLR (IN)
IO_OUT (OUT - 0)
RED_LED/IO_IN (OUT - 0) (IN)
YLW_LED (OUT - 0)
V_REF (IN - ANALOG)
LOW_SMOKE (IN - ANALOG)
HIGH_SMOKE (IN - ANALOG)
HEAT_COM (OUT - 1)
AMP_PWR/TEST (OUT - 0) (IN)
HORN (OUT - 0)
C16 10nF
R26 220R
U3
R27 10K
R43 4K7
Q3
IRED
R25 1R8
R24 330R
C14 220uF
U4
OUT
GND
R22 10K
R23 10K
R36 1K
CAL_PIN_3
LOW_SMOKE
HIGH_SMOKE
RF_LED
CAL_PIN_4
AMP_PWR
HORN
IO_OUT
RED_LED/IO_IN
YLW_LED
RF_TEST
RF_HORN

Fig.2

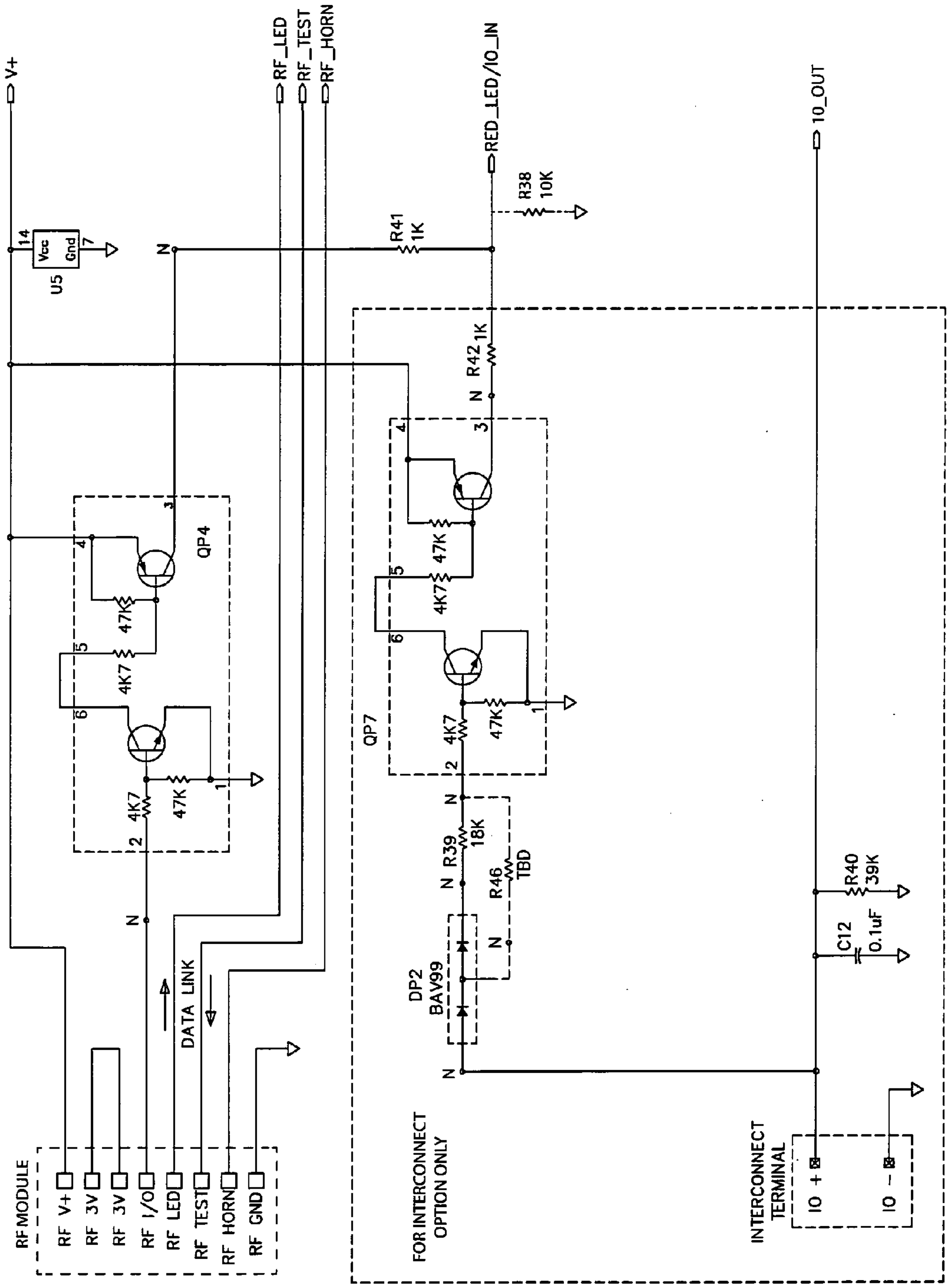
V+
U5
Vcc
Gnd
14
7
RF_LED
RF_TEST
RF_HORN
RED_LED/IO_IN
R38
10K
R41
1K
R42
1K
QP4
QP7
4K7
47K
DATA LINK
R39
18K
R46
TBD
DP2
BAV99
R40
39K
C12
0.1uF
IO_OUT
RF MODULE
RF V+
RF 3V
RF 3V
RF I/O
RF LED
RF TEST
RF HORN
RF GND
FOR INTERCONNECT OPTION ONLY
INTERCONNECT TERMINAL
IO +
IO −

Fig.3

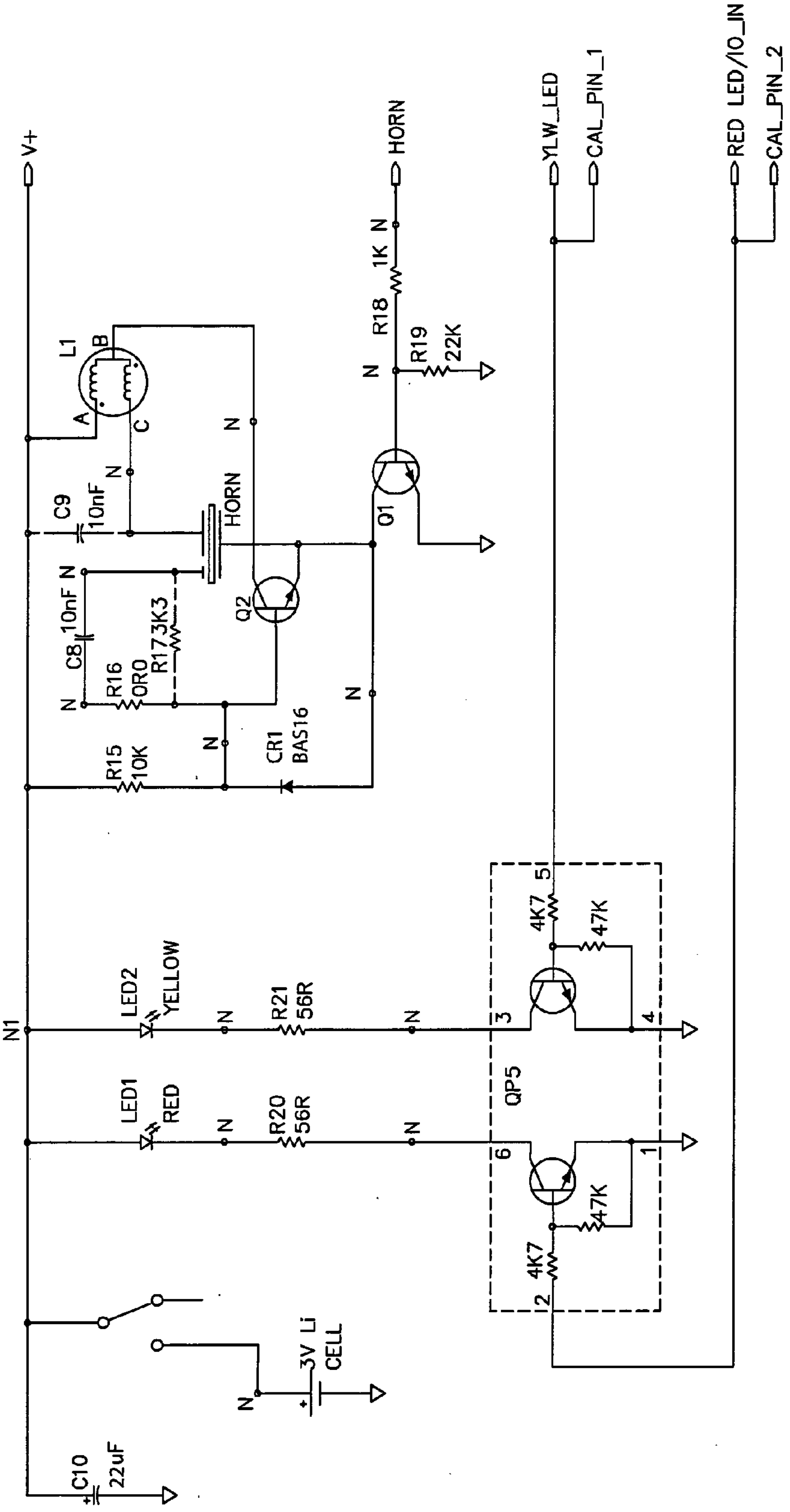
V+
HORN
YLW_LED
CAL_PIN_1
RED LED/IO_IN
CAL_PIN_2
L1
A
B
C
C9
10nF
HORN
R18
1K
R19
22K
Q1
Q2
C8
10nF
R16
0R0
R17
3K3
R15
10K
CR1
BAS16
N1
LED2
YELLOW
R21
56R
LED1
RED
R20
56R
QP5
4K7
47K
3V Li
CELL
C10
22uF

Fig.4

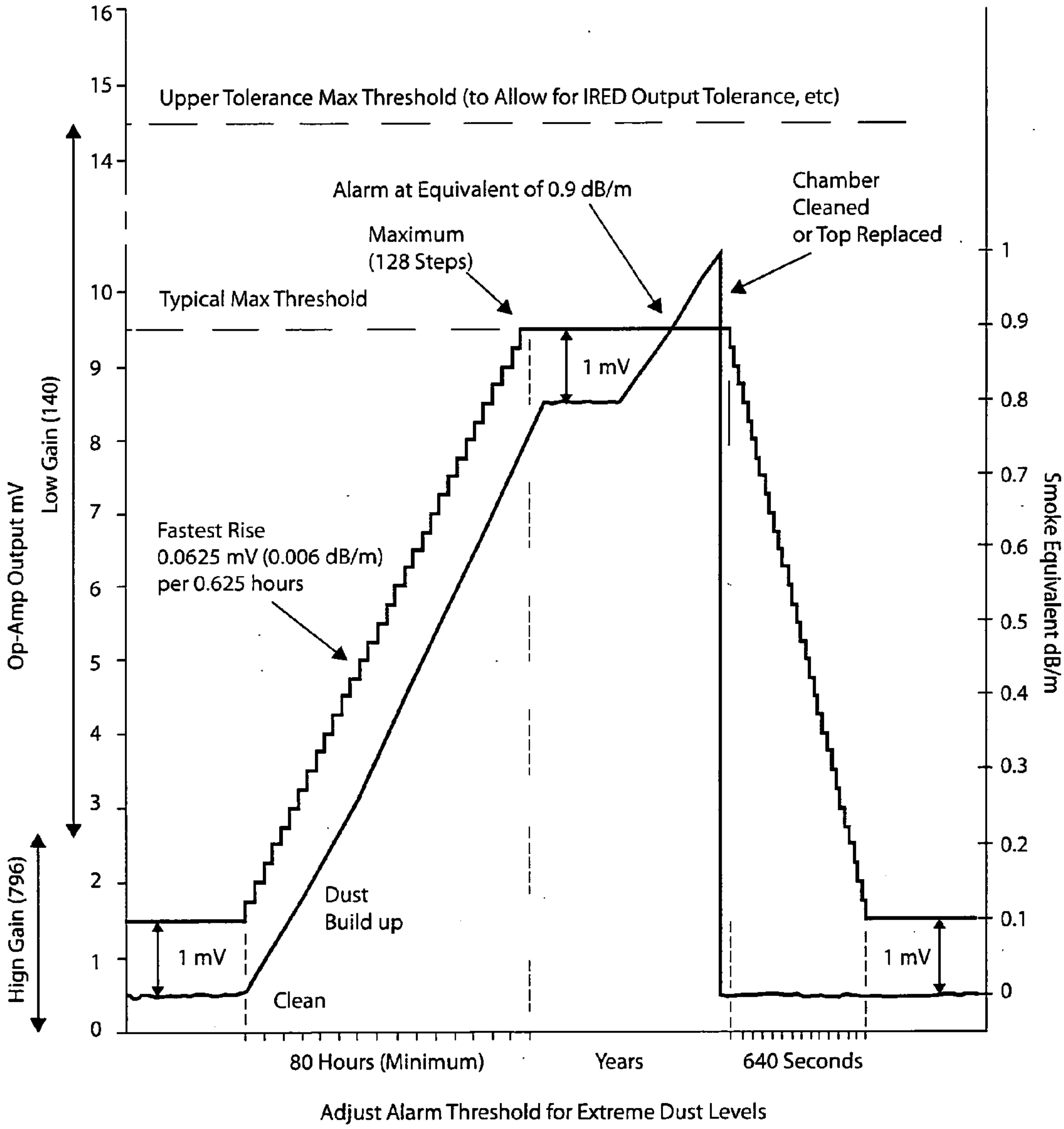
16
15
14
10
9
8
7
6
5
4
3
2
1
0
Op-Amp Output mV
Low Gain (140)
High Gain (796)
Upper Tolerance Max Threshold (to Allow for IRED Output Tolerance, etc)
Alarm at Equivalent of 0.9 dB/m
Chamber
Cleaned
or Top Replaced
Maximum
(128 Steps)
Typical Max Threshold
1 mV
Fastest Rise
0.0625 mV (0.006 dB/m)
per 0.625 hours
Dust
Build up
Clean
1 mV
1 mV
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Smoke Equivalent dB/m
80 Hours (Minimum)
Years
640 Seconds
Adjust Alarm Threshold for Extreme Dust Levels

Fig.5

	MODE	RED LED	YELLOW RED	SOUNDER
1	**Normal** Power Up Button Test (Weekly)	Off 1 Flash Rapid Flashing (every 0.5 sec)	Off 1 Flash Off	Off Off Ramps up to full sound
2	**When Fire Occurs** Unit Sensing Fire itself Sensing Fire through Interconnect	Rapid Flashing (every 0.5 sec) Off	Off Off	Full Sound Full Sound
3	**Nuisance Alarm** (< 10 min) Press Button & Release	Rapid Flashing (every 0.5 sec) 1 Flash every 8 sec. for 10 min.	Off Off	Full Sound Off
4	**Low Battery** Press Button & Release	1 Flash every 32 seconds Off for 12 Hours	Off	1 Beep with Flash Off for 12 Hours
5	**Contaminated Chamber False Alarm** Press Button & Release After 10 min press button again After 20 min if unit back in alarm press button for third time	Rapid Flashing (every 0.5 sec) 1 Flash every 8 secs 1 Flash every 8 secs Off	Off Off Off	Full Sound Off (10 minutes) Off (further 10 mins) 2 beeps 0.5 secs apart every 10 mins for 12 hrs
6	**Faulty Smoke Sensor** Press Button & Release	Off Off	1 Flash every 32 secs Off	1 Beep with Flash Off for 12 Hours
7	**Troubleshooting Diagnostics** 7.1 Memory If Unit has alarmed within 24 hours If unit has alarmed since last button press then when button pressed 7.2 To Identify Unit Having Fault Beeps[1] Press Button: Low Battery Press Button: Defective smoke Chamber 7.3 Press Button: Contaminated Chamber 7.4 When to replace Unit - Replace by date on label exceeded - And/or button test not normal	2 Flashes every 16 seconds Rapid Flashing (every 0.5 secs) Off Off Rapid Flashing every 0.5 secs	Off Off Rapid Flashing every 0.5 secs Rapid Flashing every 0.5 secs Rapid Flashing every 0.5 secs	Off Rapid Chirping Ramps Up to full sound Off Ramps Up to full sound

Fig.6

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 11 39 4005

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 4 420 746 A (MALINOWSKI WILLIAM J [US]) 13 December 1983 (1983-12-13) * column 4, lines 23-36 * -----	1-15	INV. G08B17/10 G08B29/22
A	US 4 792 797 A (TANGUAY WILLIAM P [US] ET AL) 20 December 1988 (1988-12-20) * the whole document * -----	1-15	ADD. G08B29/18
A	EP 1 098 284 A2 (E I TECHNOLOGY LTD [IE]) 9 May 2001 (2001-05-09) * paragraphs [0030] - [0039] * -----	1-15	
A	WO 02/15137 A2 (KIDDE PORTABLE EQUIPMENT INC [US]) 21 February 2002 (2002-02-21) * page 12, line 19 - page 21, line 25 * -----	1-15	
A	US 2006/164253 A1 (HARVEY ANN M [GB] ET AL) 27 July 2006 (2006-07-27) * paragraph [0005] * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			G08B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	23 May 2011	Tanguy Michotte

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

2

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 39 4005

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.

23-05-2011

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 4420746	A	13-12-1983	NONE			
US 4792797	A	20-12-1988	NONE			
EP 1098284	A2	09-05-2001	AT	266235	T	15-05-2004
			DE	60010411	D1	09-06-2004
			DE	60010411	T2	19-05-2005
			US	6437698	B1	20-08-2002
WO 0215137	A2	21-02-2002	AT	401639	T	15-08-2008
			CA	2419124	A1	21-02-2002
			EP	1579398	A2	28-09-2005
			EP	1988519	A2	05-11-2008
			US	6753786	B1	22-06-2004
US 2006164253	A1	27-07-2006	AT	362157	T	15-06-2007
			AU	2004209720	A1	19-08-2004
			CA	2515156	A1	19-08-2004
			DE	602004006380	T2	31-10-2007
			EP	1590777	A1	02-11-2005
			GB	2398155	A	11-08-2004
			WO	2004070673	A1	19-08-2004

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 1098284 A **[0010]**