Introduction

The BA45F5xxx series of MCUs include an integrated analog front end (AFE) for use by smoke detectors, allowing designers to develop related products with a minimum of external components. This application note introduces the principles and application description of this kind of AFE.

Functional Description

The following figure shows a block diagram of an independent type smoke detection alarm product. When smoke enters the product, the smoke detection circuit will generate a tiny current signal. The AFE is responsible for this current signal, converting it to a voltage signal and amplifying it, and then determining whether an alarm threshold has been reached using an A/D. After this, the product will generate an alarm output signal. This application note explains the AFE part in the figure below.

Note: 1. In the smoke detection products, the photoelectric smoke detector commonly uses optical refraction and has a labyrinth cavity.

2. Optical refraction is composed of infrared receiving and transmitting transistors.

3. The labyrinth cavity is designed to minimise any noise detected by the infrared receiver when no smoke is present.

4. When smoke enters the labyrinth cavity, the infrared radiation will be diffused, which will then be detected by the receiving part.
Operating Principles

This section introduces an independent type smoke detector alarm application circuit along with a description of AFE principles. When applied for use with different brands of labyrinth cavities or infrared pairs, there may be differences in alarm thresholds and gain settings. These need to be adjusted according to specific requirements.

Application Circuit

- Fig. 1 shows the infrared pair which is driven by ISINK0/1 which provides a constant infrared emission current. Inputs A0PI and A0NI process the infrared receiving signal.
- The infrared receiver works in reverse bias.
- The infrared receiver current is proportional to the detected smoke concentration.
- The ISINK0/1 constant current output is adjustable.
- There are two sets of ISINK for use by different smoke - white/black.
- If using the BA45F5222, then a current limiting resistor needs to be used with the LED.
**AFE Circuit Description**

- The AFE circuit is composed of two OPAs, OPA0 for current to voltage conversion and OPA1 for voltage amplification.
- SDS0 and SDS1 are used to provide a DC Bias to the OPA0 positive input terminal in order to avoid the output signal from being attenuated by the offset voltage.
- When SDS2, S1 and S0 are turned on, OPA0 forms a transimpedance amplifier with output voltage $V_{R1} + V_{OPA+}$.
- The R1 resistance value can be adjusted through SDA0PGA[5:0]. The resistance value affects the AC coupled signal magnitude to the second-level OPA.
- SDS[6:5] can select either DC coupling or AC coupling. Usually AC coupling is recommended. Here SDS[6:5]=01 and SDS4=0.
- When S3, S4 and S8 are turned on, OPA1 forms a non-inverting amplifier with an amplification of $1 + \frac{R2}{R3}$.
- The R2 and R3 resistance can be adjusted through SDA1PGA[7:0]. The resistance value affects the output signal to the A/D Converter.
- For the OPA1 output to the A/D Converter, when the A/D conversion result is greater than the threshold setting (setup by software) an alarm condition will be generated.
Both the OPA bandwidth can be adjusted. SDAnBW[1:0] is the bandwidth setting, generally set to 2MHz.

Both the OPA input offset voltages can be calibrated. Refer to the datasheet for how to do this.

SDAnEN controls the OPA enable function. In order to save power it is generally recommended to disable this along with the DC Bias after data sampling.

**Flowchart**

```
Start

DC bias enable

OPA0 enable

Delay 200\,\mu s

OPA1 enable

Delay 200\,\mu s

Isink enable

Delay 60\,\mu s

A/D Sampling

OPA \cdot DC bias and Isink disable

Smoke concentration reached threshold?

YES

Alarm

END

NO
```

**Fig. 3 Smoke Detection Flowchart**

- The OPA requires a stabilisation time of about 200\,\mu s after being enabled.
- Enable the first-level OPA before turning on the second-level OPA.
- After the Isink enable, it is necessary to have a delay before sampling using the A/D. The reason is to collect the highest point of the second-level OPA output.
- The above related time parameters may be slightly different for different environments, these should be adjusted according to actual needs.
Conclusion

This application note has introduced the AFE architecture and application description for smoke detectors, allowing it to be used quickly by users in practical applications to increase product stability.

Reference Material

For more information consult the Holtek website www.holtek.com.

Version and Modification Information

<table>
<thead>
<tr>
<th>Date</th>
<th>Author</th>
<th>Issue Release</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019.10.15</td>
<td>Jia-Chieng Wu (吳嘉乾)</td>
<td>V1.00</td>
</tr>
</tbody>
</table>

Disclaimer

All information, trademarks, logos, graphics, videos, audio clips, links and other items appearing on this website ('Information') are for reference only and is subject to change at any time without prior notice and at the discretion of Holtek Semiconductor Inc. and its related companies (hereinafter 'Holtek', 'the company', 'us', 'we' or 'our'). Whilst Holtek endeavors to ensure the accuracy of the Information on this website, no express or implied warranty is given by Holtek to the accuracy of the Information. Holtek shall bear no responsibility for any incorrectness or leakage. Holtek shall not be liable for any damages (including but not limited to computer virus, system problems or data loss) whatsoever arising in using or in connection with the use of this website by any party. There may be links in this area, which allow you to visit the websites of other companies. These websites are not controlled by Holtek. Holtek will bear no responsibility and no guarantee whatsoever Information displayed at such sites. Hyperlinks to other websites are at your own risk.

Limitation of Liability

In no event shall Holtek Limited be liable to any other party for any loss or damage whatsoever or howsoever caused directly or indirectly in connection with your access to or use of this website, the content thereon or any goods, materials or services.

Governing Law

The Disclaimer contained in the website shall be governed by and interpreted in accordance with the laws of the Republic of China. Users will submit to the non-exclusive jurisdiction of the Republic of China courts.

Update of Disclaimer

Holtek reserves the right to update the Disclaimer at any time with or without prior notice, all changes are effective immediately upon posting to the website.