**(ADDED TO PAPER)**

**Smoke Chamber Design**

The S.M.A.R.T. Alarm system employs the use of Photoelectric Sensors to detect smoke. The use of these sensors requires the design and implementation of a “Smoke Chamber” that serves as a chamber where the ambient air can enter, and thus if smoke is present it may enter as well. The most effective way to place the smoke chamber would be to have any perforation on the underside of the alarm, so that the smoke can rise into the chamber while also avoiding any light that may come from windows or the ceiling from entering the chamber. The Smoke Chamber will have two main components: an infrared or ultraviolet light emitting diode (LED) as a source and a photodiode to act as a receiver. The LED is emitting light continuously at the photodiode, and as long as the photodiode is receiving this light a current is produced, therefore if this light is interrupted then the current will stop. A lack of current stemming from the photodiode will serve as a marker for the system that smoke is present and the alarm should sound. The smoke chamber should contain as little outside light as possible, so that the outside light does not interfere with the photodiode, while allowing enough air flow for smoke to enter the chamber if present. In fact, the design of the Smoke Chamber as a Photoelectric Sensor should serve as a black box, with an input to power the LED and an output from the photodiode, so that the Alarm circuit can measure to determine the presence of smoke.

**Infrared LED**

Infrared radiation is a type of electromagnetic radiation that is often referred to as infrared light. Discovered in 1800 by Sir William Herschel, infrared radiation is invisible to the human eye however heat stemming from infrared can still be felt by touch, extending just past the red edge on the visible spectrum. Infrared radiation is classified as falling between the wavelengths of 0.75 um to 1mm. The IR LED used for measuring smoke presence in the Smoke Chamber serves as a low power option for transmitting the IR light meant to be received by the photodiode. This component must also provide the ability to emit the light normal to sensor, to avoid wear and tear that is associated with bending the leads of the component. The wavelength of the light transmitted should also match the wavelength of peak sensitivity for the photodiode, to ensure that the sensor will work.

**Table #: Comparison of 3 Infrared LED Parts**

|  |  |  |  |
| --- | --- | --- | --- |
| **Feature** | **Vishay TSKS5400S** | **Fairchild QEE113** | **OSRAM Opto SFH 4141** |
| **Wavelength** | 950 nm | 945 nm | 950 nm |
| **Beam Angle** | 30 deg | +/- 25 deg | 18 deg |
| **Radiant Intensity** | 4.5 mW/sr | 12 mW/sr | 35 Mw/sr |
| **Forward Current (IF)** | 50 mA | 50 mA | 20 mA |
| **Forward Voltage (VF)** | 1.3 V | 1.5 V | 1.3 v |
| **Power Rating** | 170 mW | 100 mW | 100 Mw |
| **Max Operating Temp.** | 85 °C | 100 °C | 85 °C |
| **Fall Time** | 450 ns | 800 ns | 12 ns |
| **Rise Time** | 400 ns | 800 ns | 12 ns |
| **Reverse Voltage** | 6 V | 5 V | 5 V |
| **Mount Style** | Through Hole | Through Hole | Through Hole |
| **Cost Per Unit** | $0.96 | $0.47 | $0.73 |

When comparing the three infrared LED options in Table it is clear to see that they are all very similar in many areas. All three have a light beam that is normal to the component, so that the LED won’t have to be bent to perform its function, and are through hole for the same purpose of directing the beam at a photodiode component. However, the QEE113 has a maximum operating temperature of 100 °C compared to 85 °C for the other two parts, which in the event of a fire may make a difference. The QEE113 also has the largest viewing angle (50°) compared to 18° and 30° for the SFH 4141 and the Vishay TSKS5400S respectively, which will allow for more light in the chamber to make contact with the photodiode. While the rise and fall time of the SFH 4141 is only 12ns, compared to 400ns and 450ns for the TSKS5400S and 800ns for the QEE113, this will not make a difference as the smoke chamber circuit will be designed so that the LED will remain on to sense any smoke in the chamber, and the rise and fall times will not be relevant. The power rating for the TSKS5400S is also higher at 170 mW, compared to 100 mW for the other two parts, putting the QEE113 and SFH 4141 at an advantage as we are seeking low power consumption for each alarm. The radiant intensity is greatest in the SFH 4141, however this would not make much of a difference in a dark environment such as the smoke chamber, as the photodiode should be able to sense the light coming from any of the three parts.

Ultimately, the Fairchild QEE113 is recommended for use for the smoke chamber. This is due to its lower power consumption, greater viewing angle, and higher maximum operating temperature. The QEE113 and SFH 4141 were close however the difference in viewing angle was a big factor, and the cost per unit also was a factor in selecting the QEE113 over the other two parts.

**Photodiode**

A photodiode is a semiconductor component designed to operate in reverse bias, that generates current when light is sensed and its photons are absorbed. However, it may also produce small amounts of current while there are no photons present. Generally, the response time of a photodiode decreases as the surface area increases in size. The most common photodiode is the solar cell, which employs its properties to convert sun light into electric current for common use. Photodiodes are not much different than regular semiconductor diodes, aside from being exposed to detect light or being designed with an optical fiber so that light to reaches the sensitive part of the component (Cox 91).

The photodiode is a p-n junction, and when a photon with enough energy reaches the diode, an electron-hole pair is created, this is often referred to as the inner photoelectric effect. In case that the absorption occurs in the depletion region of the junction, the built-in electric field of the depletion region sweeps the carriers from the junction, and the electron-holes move toward the anode while the electrons move toward the cathode, creating a photocurrent. The total current of the photodiode is made up of the sum of the photocurrent and the dark current, the current that’s generated when the photodiode is not exposed to light. Therefore, to maximize the sensitivity of the device, the dark current must be minimized (Tavernier). Photodiodes are often operated in photoconductive mode, in which the diode will be reverse biased, resulting in a reduced response time as the width of the depletion layer is increased by the additional reverse bias, thus decreasing the capacitance of the p-n junction. The reverse bias will also increase dark current while minimally affecting the change in the photocurrent (Nave).

|  |  |  |  |
| --- | --- | --- | --- |
| **Feature** | **OSRAM SFH 206K** |  |  |
| **Mounting Style** | Through Hole |  |  |
| **Peak Wavelength** | 850 nm |  |  |
| **Dark Current** | 2 nA |  |  |
| **Reverse Voltage (VR)** | 32 V |  |  |
| **Rise Time** | 20 ns |  |  |
| **Fall Time** | 20 ns |  |  |
| **Max Operating Temp** | 100 °C |  |  |
| **Forward Current (IF)** | 100 mA |  |  |
| **Forward Voltage (VF)** | 1.3 V |  |  |
| **Power Dissipation** | 150 mW |  |  |
| **Photocurrent** | 800 uA |  |  |
| **Cost Per Unit** | $1.12 |  |  |

**Additional Notes**

* We should add an LED that serves as “detector is working” display
* Maybe we can use “test switch” to show our system works rather than using fire and real smoke
* Research smoke detector algorithms
* We need to notify of low battery in noticeable “smart” manner (email)
* Research life expectancy of sensors
* Combination algorithms of several sensors
* <http://www.ssspl.org/uploads/Products/Pdf/firealarmsystem.pdf>
* Save smoke chamber case for design section
* MQ-2 sensor research

**To Quantify**

* Sensitivity in % per meter
* Life Expectancy of sensor
* Accuracy of sensor
* Response time

**Infrared LEDs**

QEE113 (my recommendation):

<http://www.mouser.com/ProductDetail/Fairchild-Semiconductor/QEE113/?qs=sGAEpiMZZMvAL21a%2fDhxMuzwbd0aUTVlanksvcoBHPo%3d>

Vishaw TSKS:

<http://www.mouser.com/ProductDetail/Vishay-Semiconductors/TSKS5400S/?qs=sGAEpiMZZMvAL21a%2fDhxMjzY1Rb8bqZ%2fASqyBcGF3ws%3d>

OSRAM 4141:

<http://www.mouser.com/ProductDetail/OSRAM-Opto-Semiconductors/SFH-4141/?qs=sGAEpiMZZMvAL21a%2fDhxMman1vtIzMd5N8EDH%252b52PjRf7B7Njj6hfQ%3d%3d>

**References**

Cox, James F. Fundamentals of Linear Electronics: Integrated and Discrete. Albany, NY: Delmar, 2002. Print.

Nave, Carl. "Photodiode Light Detector." *Photodetectors*. HyperPhysics, n.d. Web. 07 Mar. 2017. <http://hyperphysics.phy-astr.gsu.edu/hbase/Electronic/photdet.html>.

Tavernier, Filip, and Michiel Stevaert. “Chapter 3: From Light to Electric Current – The Photodiode.” High-speed Optical Receivers with Integrated Photodiode in Nanoscale CMOS. NewYork: Springer, 2011. N. pag. Print.