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A Design of Smart RFID System for Toxic Gases Monitoring

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Abstract

This paper proposed a design of smart RFID system for toxic gases monitoring. In the daily life the toxic gases that could be harm for us are hydrogen sulfide, ammonia gas, carbon monoxide, etc. Workers are very easy to be poisoned by these gases. So a rapid and low cost method of preventing toxic gases poisoning is needed. We design a smart RFID system to monitor the concentration of different gases. Proposed system consists of smart RFID tag, humidity sensor, hydrogen sulfide sensor, ammonia sensor, reader, and server. This monitoring system can show the concentration of different toxic gases for three grades, Safe, Warning, Risk. In order to confirm the usefulness of the proposed system, we performed experiments on mackerels. With the smart RFID system, we estimated the concentration of toxic gases successfully.

Keywords: *Smart RFID system, Toxic Gas Monitoring, Hydrogen Sulfide Sensor, Ammonia Sensor, Concentration of Gas*

1. Introduction

Toxic gases exist almost everywhere in the daily life. Everyone has the opportunity to contact with toxic gases. Toxic gases such as Carbon monoxide (CO), Hydrogen sulfide (H_2S), Ammonia (NH_3) even a little could be big harm to human. The miners could be poisoned by carbon monoxide when they are working in the mountain. The fishermen face a risk of hydrogen sulfide poisoning when they clean the cabin of fishing vessel. The warehouse that stored meat could be dangerous because meat could release a large amount of ammonia [1].

Hydrogen sulfide is a colorless toxic gas with the characteristic foul odor of rotten eggs. When the concentration of hydrogen sulfide is at 100-150 ppm the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears, often together with awareness of danger. When the concentration of hydrogen sulfide is at 320-530 ppm, it leads to pulmonary edema with the possibility of death [2].

Ammonia is a colorless gas with a characteristic pungent smell. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers. Ammonia, both directly or indirectly, is also a building-block for the synthesis of many pharmaceuticals and is used in many commercial cleaning products. Although in wide use, ammonia is both caustic and hazardous. The global industrial production of ammonia for 2012 was anticipated to be 198 million tones, a 35% increase over the estimated 2006 global output of 146.5 million tones [3].

In this paper, we propose the design of smart RFID system for monitoring different toxic gases. The proposed system consists of smart RFID tag, gas sensor, humidity sensor, reader, and server. The smart RFID Tag is very small and it is very convenient to be attached at any

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environment. The smart RFID Tag can be connected with different gas sensors. With RFID technology, we can get the gas data easily at closed space, so workers can monitor the concentration of different gases. In order to confirm the usefulness of the proposed system, we perform experiments on mackerels. The concentration can be divided into 3 grades: Safe, Warning, Risk. Workers can take different safety measures according to the concentration of different gases.

2. The Proposed Smart RFID System

2.1. The Smart RFID Tag

The block diagram of the smart RFID Tag is shown Figure 1 [4]. The Smart RFID tag consists of 950 MHz antenna, RF front-end, power harvester, demodulator, modulator, MSP 430 and battery. Power harvester supplies power to MSP 430. Battery supplies power to external sensors. Demodulator transmits converted RF data to MSP430 using ASK method. Modulator transmits digital signal of MSP430 to reader using the backscatter method. MSP430 processes the sensor data and converts it to digital data. The manufactured smart RFID tag is Semi-Passive type tag worked by both RF signal power and battery.

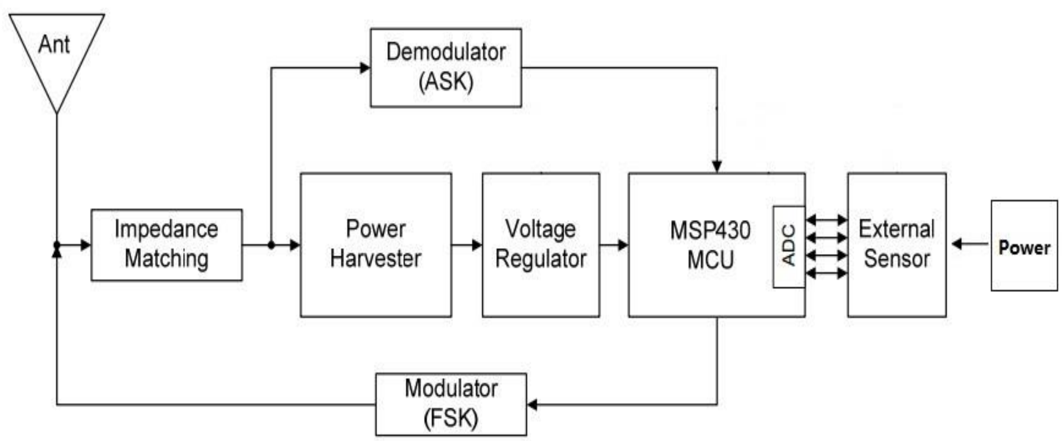

Figure 1. The Block Diagram of Smart RFID Tag

A schematic of the smart RFID tag analog circuitry is shown in Figure 2 [5].The smart RFID tag analog front end differs slightly in purpose from that of conventional RFID tags. Due to the relatively high power consumption of smart RFID tag, the rectifier is designed to supply more current than ordinary tags. This circuit is excited by commercial, EPC Class 1 Generation 1 compliant readers operating at 902-928 MHz with an allowable transmission power of 4WEIRP (Effective Isotropic Radiated Power).

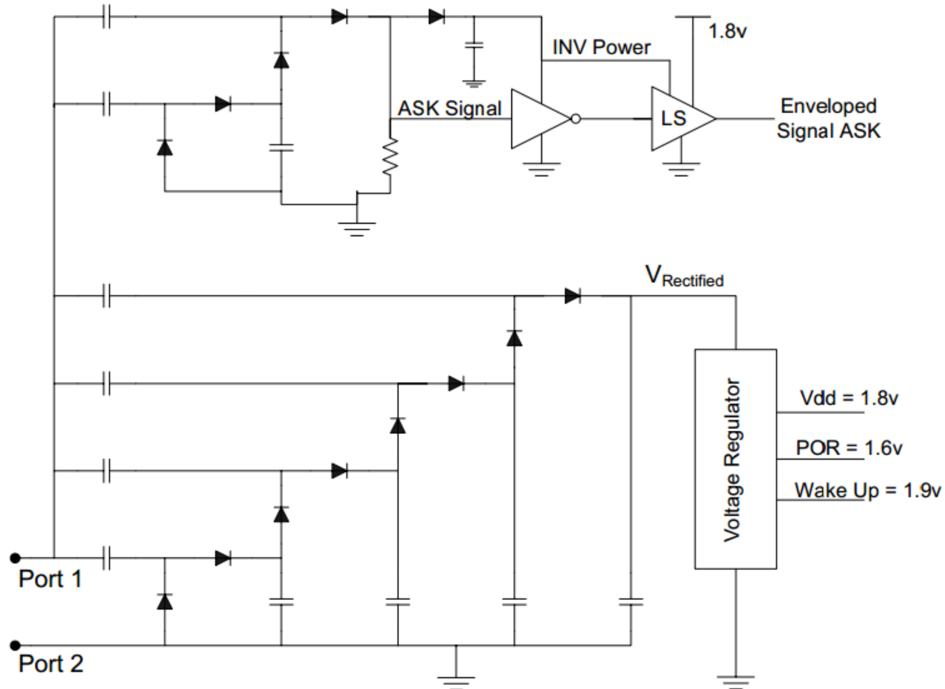

Figure 2. Schematic of RFID Tag Power Harvesting and Communication Circuit

Due to loss in signal strength over transmission distance, there is potentially very little power for the tag. Therefore, efficient conversion of the incoming RF energy to DC power for the tag is an important design consideration. A matching network provides maximum power transfer from the antenna to the rectifier, and a 5 stage voltage doubling circuit converts the incoming power to voltage. Low threshold RF Schottky diodes are used to maximize the voltage output of the rectifier. Finally, this rectified DC voltage is stored in a large capacitor and supplied to a 1.8V regulator to power the smart RFID tag.

To tune the antenna, the two dipole branches were mounted to an SMA connector that was then connected to a network analyzer, and the dipole length was optimized for the 902MHz to 928MHz band. Next, an SMA connector was attached to the tag board in place of the antenna and the tag was attached to the network analyzer, which was set to sweep from 902-928MHz at a power of 0dBm. The microcontroller was programmed to remain in LPM4 sleep mode to minimize its power consumption. The tag's discreet matching network, composed of a series inductor and parallel trimmable capacitor, was tuned until the output voltage of the tag was maximized. Note that the power harvester is a non-linear device, and its efficiency is highly load-dependent. Ultimately, the front end must be tuned to provide maximum output voltage in the presence of the desired load. Optimizing the matching network for the load of the microcontroller in its LPM4 sleep state effectively maximizes read range. To maximize read rate at close range, or power delivered at close range, one would tune the matching network differently.

Figure 3 shows the manufactured smart RFID tag. This smart RFID tag is a sensing and computing device that is powered and read by off the shelf UHF RFID readers. This tag has on board microcontrollers that can sample a variety of sensing devices, creating a wirelessly-networked sensor device. The smart RFID tag has powered everything from analog light sensors to temperature sensors to strain gauges [5-6].

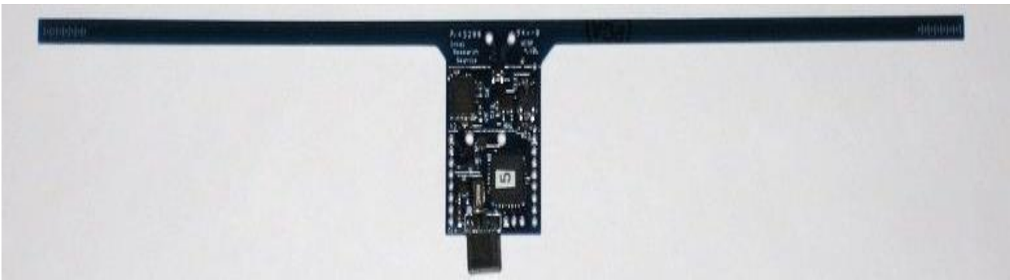

Figure 3. Smart RFID Tag

2.2. External Sensors

2.2.1. Humidity Sensor: The humidity sensor of the proposed system used a commercial product MM1001. Figure 4 shows the humidity sensor and the characteristics of the humidity sensor are shown in Table 1.

Figure 4. Humidity Sensor

Table 1. Characteristics of Humidity Sensor

Characteristics	Content
Supply Voltage	4V to 5.5V
Output signal	0.6- 2.7V DC
Detecting range	20-95%RH
Accuracy	±5%RH

2.2.2. Hydrogen Sulfide Sensor: We use MQ-136 as the main test sensor, which has a good sensitivity for hydrogen sulfide. Sensitive material of MQ136 gas sensor is SnO_2, which with lower conductivity in clean air. When the target H_2S exist, the sensor's conductivity is higher along with the gas concentration rising. Figure 5 shows the typical sensitivity a characteristic for several gases and Figure 6 is the hydrogen sulfide sensor [2, 7].

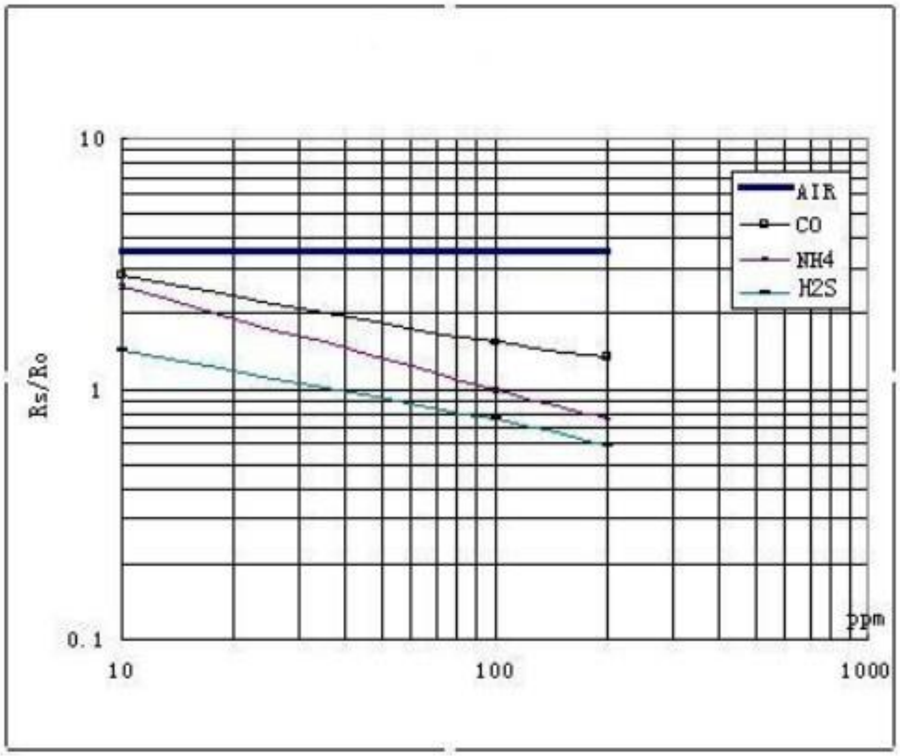

Figure 5. Characteristics of Hydrogen Sulfide Sensor

Figure 6. Hydrogen Sulfide Sensor

2.2.3. Ammonia Sensor: We use MiCS-5914 as another test sensor, which has a good sensitivity for ammonia. Figure 7 shows MiCS-5914 and the typical sensitivity characteristics for ammonia gas and Figure 8 is the ammonia sensor [3, 8].

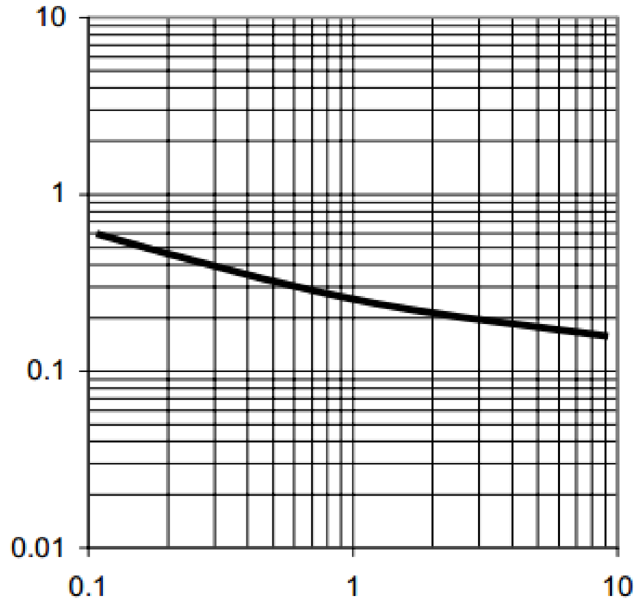

Figure 7. Characteristics of Ammonia Sensor

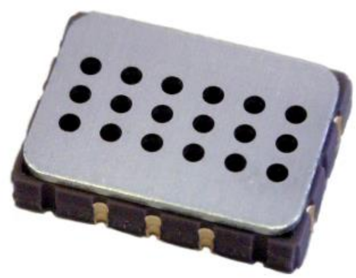

Figure 8. Ammonia sensor

2.2. External Sensors

Reader is speedway revolution UHF RFID reader made by IMPINJ. Figure 9 is reader and Table 2 is the specification of reader [9].

Figure 9. RFID Reader

Table 2. Specification of Reader

Characteristics	Content
Interface Protocol	EPC global UHF Class 1 Gen 2 / ISO 18000-6C
RF Frequency	900Mhz - 930Mhz
RF Range	10cm - 10m
Transmit Power	10.0 ~ 30.0 dBm
Power Consumption	24V

3. Toxic Gases Monitoring

For H2S, 50 ppm is the acceptable maximum peak above the ceiling concentration for an 8 hour shift, with a maximum duration of 10 minutes. 50–100 ppm leads to eye damage. At 100–150 ppm the olfactory nerve is paralyzed after a few inhalations, and the sense of smell disappears, often together with awareness of danger [2, 10-11]. Table 3 shows the relation between the sensor output and the concentration of H2S.

Table 3. Hydrogen Sulfide Toxicity in Humans

Status	H2S Sensor Out (mV)	Content
Safe	<1000	<50ppm
Warning	1000-2000	50-100ppm
Risk	>2000	>100pp

For NH_3, at 50-100 ppm mild eye, nose, and throat irritation; tolerance may develop in 1-2 weeks with no adverse effects thereafter. At 100-140 ppm moderate eye irritation; no long-term sequelae with exposures of less than 2 hours [3, 10, 12]. Table 4 shows the relation between the sensor output and the concentration of NH_3.

Table 4. Ammonia Toxicity in Humans

Status	H2S Sensor Out (mV)	Content
Safe	<750	<50ppm
Warning	750-1750	50-100ppm
Risk	>1750	>100pp

4. Experiment

As humidity is also a factor that cause gas poisoning. We collected humidity, ammonia, hydrogen sulfide of the environment at the same time. We perform experiments simply on the mackerels in the laboratory. Fish release ammonia gas and hydrogen sulfide during the storage. Figure 10 is the experimental picture. The box is simulating the closed environment. Smart RFID Tag and sensors are inside of the box. Through the experiment, we measured the output of H2S sensor and ammonia sensor and the humidity of the environment.

Figure 10. Experimental Picture

We measured H_2S concentration and NH_3 concentration in a closed environment. Through simulating the closed environment, we get the H_2S concentration and NH_3 concentration successfully. The concentration can be divided into 3 grades as Figure 11 and Figure 12. Figure 11 shows the concentration of H_2S in a closed environment. Figure 12 shows the concentration of ammonia. The information can be shown on the program as Figure 13.

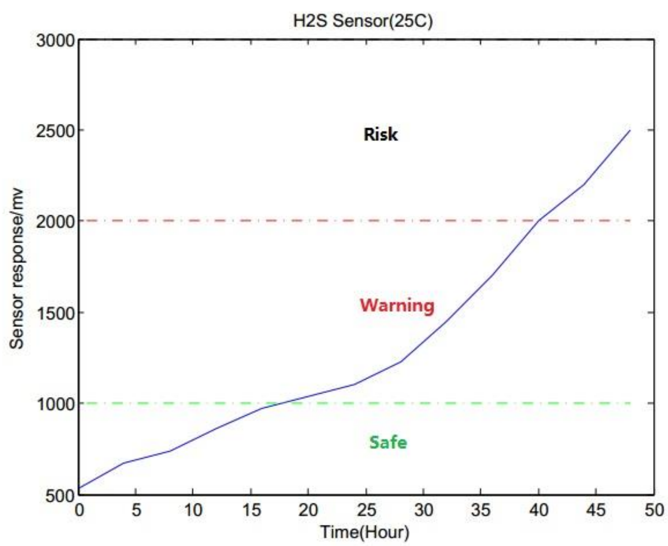

Figure 11. Concentration of H_2S at 25 ºC (48 Hours)

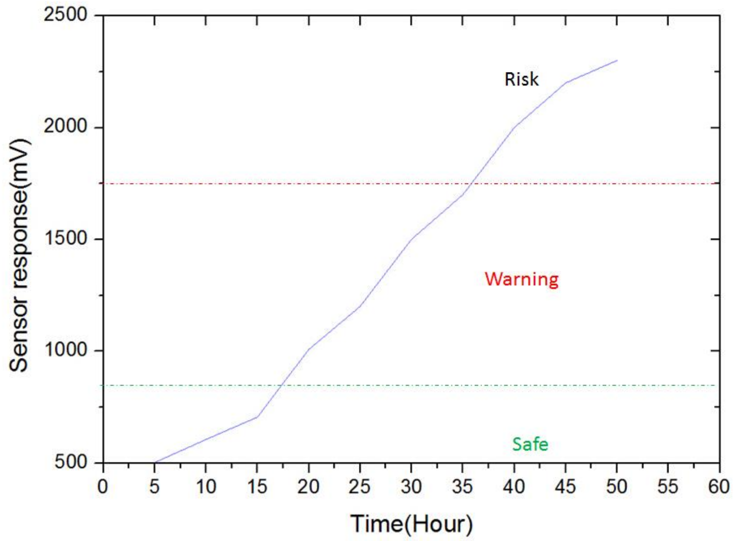

Figure 12. Concentration of NH_3 at 25 ºC (48 Hours)

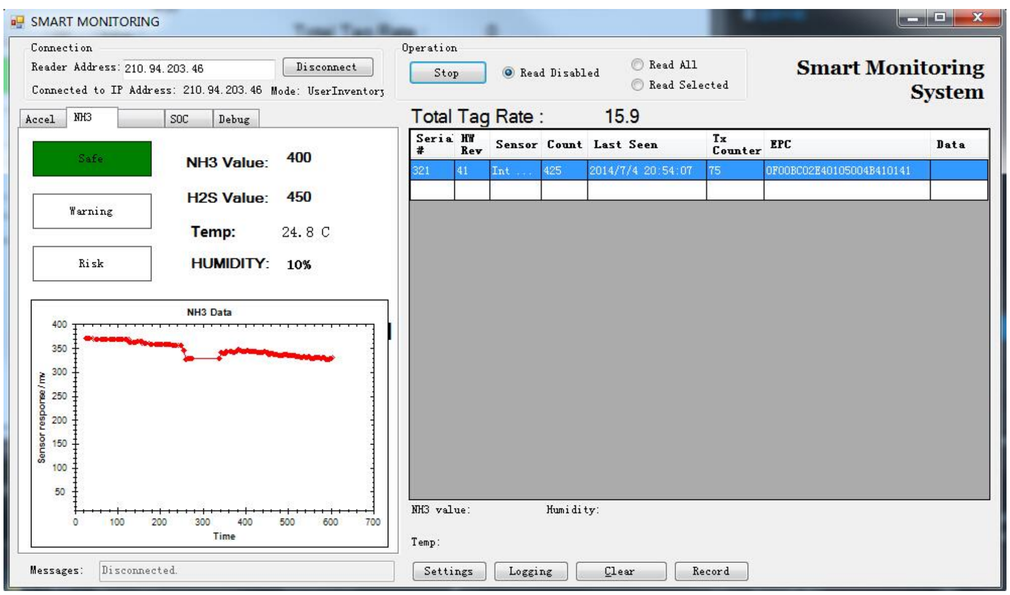

Figure 13. Main Screen of Monitoring System

5. Conclusion

In this paper, we proposed a design of smart RFID system for toxic gases monitoring. We test ammonia gas and hydrogen sulfide gas in this experiment. Through monitoring the concentration of hydrogen sulfide and ammonia, we can know the dangerous situation in advance. Proposed system consists of smart RFID tag, humidity sensor, H_2S sensor, NH_3 sensor, reader, and server. The proposed smart RFID tag measured ammonia and hydrogen sulfide of environment during the transportation and storage. The measured information was calculated and divided into 3 degree such as safe, warning, risk. In order to confirm the usefulness of the proposed system, we performed experiments on the mackerels in the laboratory. The experimental results show that was confirmed the performance of the monitoring system for predicting the risk. Workers can see the safe situation directly through the monitoring system.

Acknowledgements

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