A High-Precision NDIR CO2 Sensing Module for ZigBee Applications

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***Abstract*— NDIR-based CO2 sensor is commonly used in the field of environmental monitoring due to relatively high accuracy compared with that of a chemical CO2 gas sensor. This paper presents a wireless sensing system with a low-cost Non-Dispersive Infra-Red (NDIR) sensor module used to determine gas concentration in a remote air quality monitoring system. Unlike the chemical CO2 gas sensor, the proposed sensing system has new features not only for reaching high precision criteria and for enhancing long-term stability. According to the results obtained, the wireless sensing system provides an important feature in wireless sensor applications with a minimum reduction of the node operating life, where precise CO2 monitoring is necessary.**

***Keywords*— carbon dioxide, wireless sensing system, ventilation**

1. INTRODUCTION

Carbon dioxide (CO2) measurements in a passenger cabin become an important issue since human beings are acting as a source by exhaling CO2. The U.S. EPA recommends a maximum concentration of carbon dioxide of 1000 ppm for continuous exposure. ASHRAE standard 62-1989 recommends an indoor air ventilation standard of 20 cfm per person of outdoor air or a CO2 level which is below 1000 ppm [1]. NIOSH recommends a maximum concentration of carbon dioxide of 10000 ppm, but OSHA recommends that carbon dioxide level would have to increase to about 14000 ppm. In summary, the high concentration of carbon dioxide may act human beings for a long period of time with irreversible tissue damage.

However, most CO2 gas sensors in the market need more power to reach their stability. It is difficult to make their use in portable battery-operated application especially in wireless sensor networks. The goal of this paper is the use of non-dispersive infrared sensors, which present relative low power consumption but are highly stable in order to avoid any recalibration during the lifetime of the vehicle [2]. An NDIR sensor consists of an infrared source, optical cavity, dual channel detector and internal thermistor. The dual channel detector in an NDIR sensor consists of two filter windows. The active filter is centred on an infrared absorption peak of the target molecule and the reference window is in portion of the infrared spectrum where there are absorption bands. The measured intensity of radiation at the active detector is therefore the sum of an absorbing intensity and a passive intensity. Thus, this paper presents the design of a low-power ZigBee system which facilitates the measurements of the carbon dioxide concentration in a passenger cabin.

This paper is organized as follows. In section 2, the system architecture is reviewed. Sections 3 describes the sensor interface, detailing the operation of its building blocks. Conclusions are drawn in Section 4.

2. HARDWARE

The wireless sensor node used in this research is Octopus-II. The whole system consists of a 16-bit microcontroller, a 2.4 GHz IEEE 802.15.4 compliant RF transceiver, and a Bluetooth transceiver. The sensing results can be delivered to your remote device with Bluetooth technology.

2.1. Octopus-II

Octopus-II is the next-generation wireless sensor platform for extremely low power, low data-rate, sensor network applications designed with the dual goal of development ease and fault tolerance[7,8]. The platform is developed by National Tsing Hua University, as shown in Figure 1. This node chose the 16-bit low-power MSP430 microprocessor. This module operates at 4 MHz system frequency and provides an external expansion slot for up to 51 I/O pins. These pins include three 12-bit ADC channels and allow us to easily link the carbon dioxide sensor. In addition, we use the C language to develop a wireless communication firmware. The advantage of using C language can get the best performance due to control the hardware directly.

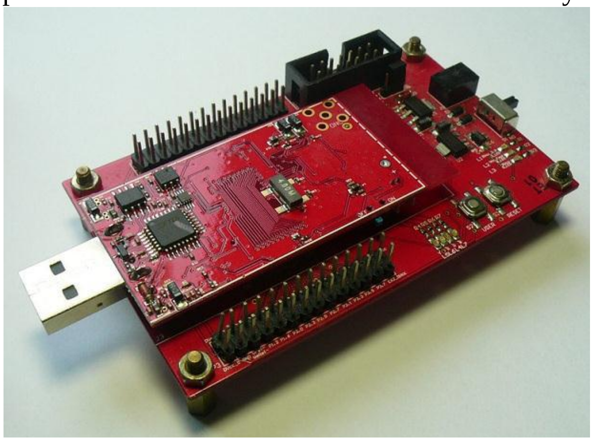

Fig. 1 Octopus-II is connected with the Dock

2.2. ZG01

ZG01 is a carbon dioxide and temperature sensor which is designed by ZyAura company. ZG01 is a non-dispersive infrared (NDIR) gas sensor used to measure the CO2 concentration in an open air environment. The NDIR sensor consists of an infrared source with a determined frequency, an optical cavity where the gas to be detected can be diffused, a dual channel detector and an internal thermistor. The measurement range of ZG01 is 0 ~ 3000 ppm. ZG01 can communicate with Octopus-II by using SPI interface. Without any calibration ZG01 can achieve an accuracy of better than ±50 ppm over the whole temperature, pressure, and humidity ranges.

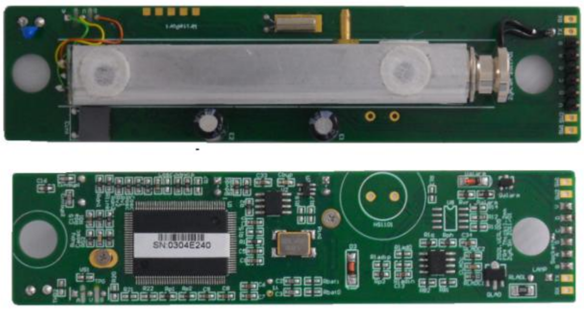

Fig. 2 ZG01 sensor

2.3. Temperature and Humidity Sensor

SHT11[9] digital humidity and temperature sensor is the all-round version of the reflow solderable humidity sensor series that combines decent accuracy at a competitive price. The sensor is designed by SENSIRON and is equipped with Octopus-II, as shown in Figure 3. In addition, NDIR detectors are highly sensitive to the ambient temperature, making necessary to constantly monitor the temperature to compensate the associated output drift. The SHT11 is used for this purpose.

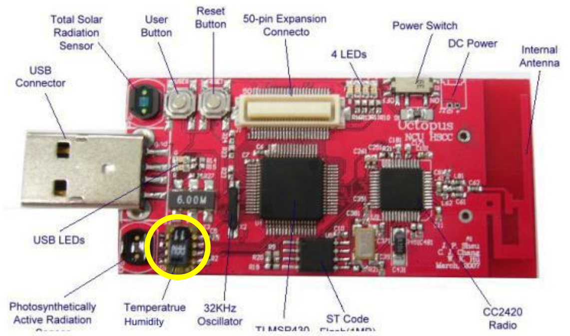

Fig. 3 SHT11 temperature and humidity sensor

3. SYSTEM IMPLEMENTATION

3.1. System Framework

We use the dock to connect ZG01 and the sensor can transmit CO2 gas information to Octopus-II through SPI, as shown in Figure 4. The other I/O pins on the dock can be used to warm users when the variation of the gas is too high. Finally, the dock can transmit the message by using Bluetooth or ZigBee communication.

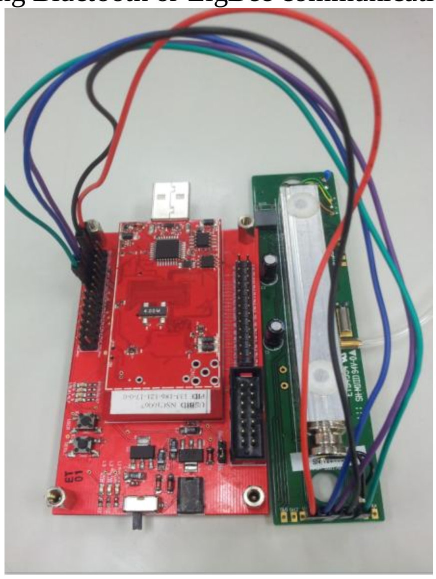

Fig. 4 An NDIR CO_2 monitor system with ZigBee technology

3.2. SPI

A serial peripheral interface (SPI) is a low-cost, four-wire, full-duplex synchronous serial communication data stream interface that operates in a master-slave relationship. Typically there are four lines common to the sensors.

CS (Chip Select) – The pin on each device that the microcontroller can use to enable and disable the sensor.

SCK (Serial Clcok) – The clock pulses which synchronize data transmission generated by the microconterller.

MISO (Master In Slaver Out) – The sensor line for sending data to the microcontroller.

MOSI (Master Out Slaver In) – The microcontroller line for sending data to the sensor.

SPI can easily be used for communication between Octopus-II and the NDIR sensor. When the sensor want to send data to the MSP430, the sensor device based on the SCLK pin from high to low, and the microcontroller will read the sensing information from the MISO line. When the microcontroller wants to send command to the sensor, sensor will read the information passed from the Master through the MISO pin. In this paper, the communication protocol of ZG01 is shown in the following Figure 5. ZG01 will send a complete packet at a serial clock at 500μs cycle.

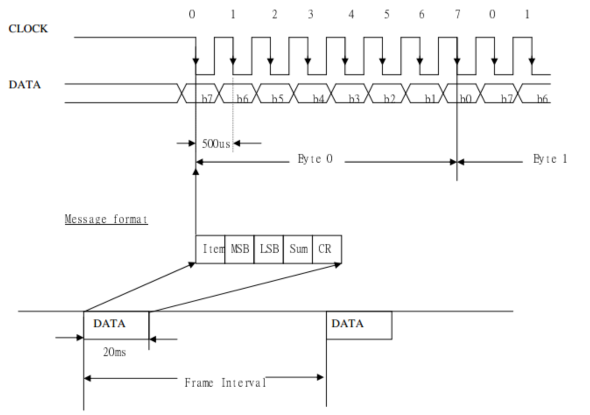

Fig. 5 A complete sensing packet in ZG01

3.3 Concentration of Carbon Dioxide

According to the recommendations of ASHRAE, the concentration of CO2 at 600-1000 ppm will let people to feel uncomfortable. People may feel sleepy at 1000-2500 ppm. Their health will be hazardous at 2500-5000 ppm. People will seriously affect the safety of the life over 5000 ppm and eight hours.

If carbon dioxide concentration is below 600 ppm, the green LED in the monitoring system will light. The yellow LED in the monitoring system will light when carbon dioxide concentration is between 600-1000 ppm. The red LED will light when carbon dioxide concentration is over 2500 ppm.

4. CONCLUSIONS

In this paper, we design a wireless sensing system based on ZigBee technology for monitoring and identifying the variation of ventilation in the car space. The embedded wireless system combined with an Octopus-II and a carbon dioxide sensor, ZG01. According to the variation of ventilation in the car space, the driver can open the car window to reduce the density of carbon dioxide.

In the future, the information of carbon dioxide will upload to the cloud computing system. We expect the findings will assist in studying the distribution of airflow in indoor work space, and hence this embedding device is a variable monitoring strategy for tracing and monitoring the ventilation performance and ventilation effectiveness.

ACKNOWLEDGMENT

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