Advanced Engineering Forum *Online: 2011-12-22*
ISSN: 2234-991X, Vols. 2-3, pp 541-546
doi:10.4028/www.scientific.net/AEF.2-3.541

A Study on CO_2/CO Dual Sensor Module by NDIR Method

ByungSeok Lee[1, a], KyoungHoon Kim[2,b], YoungDeok Yeom[3,c], HyunTae Kim[4,d], Joon Hwa Lee[5, e], Gyu-Sik Kim[6,f], Chung Hyuk Lim[7,g]

[1~6]The School of Electrical & Computer Engineering, The University Of Seoul, Korea

[7]Convex Inc., Korea

[1]byungseok@uos.ac.kr, [2]chaos7427@uos.ac.kr, [3]yydsky@uos.ac.kr, [4]hyubn0601@uos.ac.kr,

[5]joonhwa@uos.ac.kr(corresponding author), [6]gskim318@uos.ac.kr, [7]chyim@convex2000.com

Keywords: NDIR method, CO_2/CO Dual Sensor Module, Optical Chamber, IR Lamp, IR Detector

Abstract. This research deals with the CO_2/CO Dual Sensor Module measuring CO_2 and CO, that is the representative environmental harmful material, simultaneously. In the measurement of the CO_2 and CO generally, the Non-Dispersive InfraRed method(NDIR method) is used for the precise measurement and durability. This method is to measure the concentration of the gas by using the Lambert-beer rule. When measuring the gas density with the NDIR method, the important factor is the apparatus for being called an optical chamber consisting of the emitter sensor and detector sensor are used for measuring concentration of the gas. Thus, this paper introduces an optical chamber of the new way of using the NDIR method and through this, shows an experimental result of the CO_2 gas concentration measurement and it presents possibility for measurement of the concentration of the CO.

Introduction

The effort about the environmental pollutant regulation is raising while the concern about the environment increases. Greenhouse gas, especially from 1970 to 2004 was increased by 70%. Thus, all countries of the world try in order to reduce the emission quantity of the CO_2 which is the host of the global warming among the greenhouse gas. And institutionally, the emission quantity of the CO_2 is regulated. In addition, because of bringing the detrimental result as the toxic gas mainly generated in the misfire process with the small quantity to the human body, the discharge reduction of CO and monitoring are needed.

The NDIR(Non Dispersive InfraRed) method is widely used as the method for the measurement of the CO_2 and CO. The NDIR method is to measure the concentration of the gas through the light energy absorption of the specific gaseous molecule. As to this method, the concentration measurement which is accurate in comparison with the small size · low cost electrochemical type or semiconductor method is possible and the selectivity of the specific gas is excellent. And there is the advantage of minimizing the maintenance and complement with the long lifetime more than 5~10 year. However, the efficient focusing of light incident in the gaseous molecule, the minimization of the light loss by reflection, amplification of the weak signal in the detector part, analog to digital conversion, the minimization of the noise are important consideration factors in the NDIR method. Therefore, this research presents the NDIR method and sensors, a new optical chamber measuring CO_2 and CO simultaneously, and the noise minimization plan, the circuit for the fine signal amplification, the voltage value measurement changed by the constant concentration of the CO_2.

NDIR method and Sensor

Generally, the wavelength of 3㎛ ~ 8㎛ (mid wavelength Infrared) is used in the NDIR method. An absorption wavelength representing the large-scale absorption rate is respectively 4.26㎛, 4.64㎛ in mid wavelength Infrared band. By the absorption of the above infrared wavelength, Lambert-Beer's law that combines the Beer's law(i.e.; the absorption rate in the gas or solution is proportional to the number of molecules in the route of light at the absorber and that is unrelated with the dilution or

pressure) with the Lambert's law(i.e.; the log value of the ratio with radiated light intensity and transmission light intensity penetrating the absorber are proportional to the thickness of the absorber) is represented in Eq. (1). And the method measuring the concentration of the specific gas by the Lambert-Beer's law is the NDIR method.

$$I = I_o^{-\sigma Pd} \tag{1}$$

In the Eq. (1), I is the light intensity in the detector part, I_o is the light intensity in the Emitter part, σ is the cross section in the absorber, P is the number of molecules per cm^3(that is gas concentration in the absorber), d is the thickness in the absorber[1][2].

The heated nichrome wire wound spirally or hot gas was used as a emitter sensor for the NDIR method in the first stage. However, recently IR Lamp or IR LED is used as the light source of the light emitter sensor. In this research the emitter sensor is the IR Lamp that is the small size with the tungsten filament. On the other hand photo resistor consisting of the PbSe that is the material reacted in the infrared range of 1.5㎛~5.2㎛ used as the IR detector is selected for the detector sensor. The principal characteristic of the selected sensor is as follow[6].

Table 1 IR Lamp EMIRS2000(with reflector) characteristics

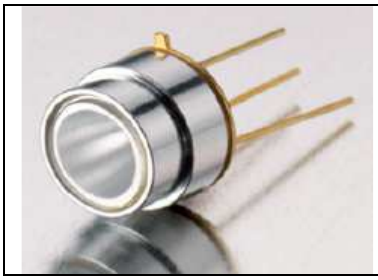	Emissivity	0.95 (2㎛ ~ 16㎛)
	Life time	>10 years
	Electrical Input Power	450mW
	Operating Voltage	5.7V
	Working temperature	456℃
	Case Temperature	47℃ (50% duty cycle, 30Hz, 450mW)

Table 2 IR Detector PR43-TEC(with reflector) characteristics

	Material	0.95 (2㎛ ~ 16㎛)
	Wavelength Range(50%)	1.0 ~ 4.4㎛
	Zero bias resistance(10mV)	0.15 ~ 0.35 MΩ
	Voltage / Watt	200 ~ 500 V/W
	Photosensitive area	2.0 X 1.9mm^2
	Sensitivity D*	(5 ~ 10)x 10 $cmHz^{1/2}/W$

Optical Chamber

When measuring the concentration of the gas by using the NDIR method, the chamber which emits and detects the light is needed. This chamber is called as the optical chamber. The optical chamber is made of the material in which the reflectivity is high in order to reduce the loss of the light. The reflectivity according to the main material in 4.2㎛~4.7㎛ wavelength band, the band is the range which is used for measuring CO_2 and CO, is big to the order of Au>Ag>Al. The reflectivity of these materials is more than nearly 95%[5]. Considering relatively high reflectance and cost, an optical chamber which is presented in this research was designed in aluminum. In addition, by using the interior linear motor, an optical chamber was designed to change the optical path for measuring the CO_2 and CO simultaneously. In other words, because of the weak reaction to the light of CO gas on molecular structure, long optical path is needed in an optical chamber to measure the light intensity in the detector sensor. And an optical chamber is to calculate the ratio of the measurement value in the short optical path and the measurement value in the long optical path for minimized effect of

temperature including humidity. Therefore, the following device for reflecting the incident light in order to reduce amount of light which is lost by the changes in optical path in one optical chamber was designed and the following new type of an optical chamber was devised.

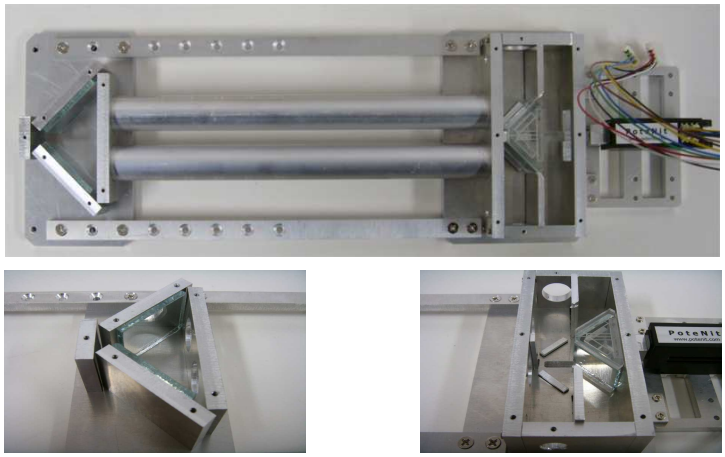

Fig. 1. Optical Chamber to change the optical path
(Top : Overall, Left : reflector, Right : reflector, linear motor & Emitter, Detector)

The reflecting plate moves back and forth. At this time, the light of the emitter sensor directly radiated to the detector sensor or radiates to the detector sensor through the reflected path through the long optical path. And simultaneously the optical chamber measures the gas density with 2 kinds of other paths as shown in figure 1.

Circuit Part and Minimization of Power Noise

By using the devised optical chamber, the radiated light of the emitter sensor is sensed in the detector sensor and 2-stage amplifier circuit was used to amplify the fine change by 1,000 times of ratio and then the voltage change of the detector sensor is sensed.

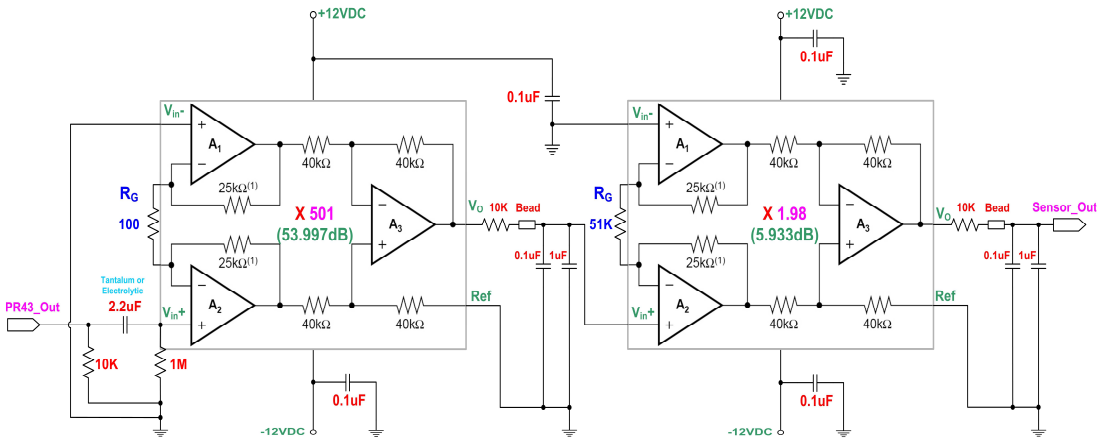

Fig. 2. 2-Stage OP Amplifier Circuit

In addition, by using 24bit Δ ∑ ADC(ADS1253), the fine voltage change is measured. The selected ADC chip is an A/D Converter which is suitable for the gas concentration measurement for the high resolution measurement as a chip having the effective bit of 19bit in the maximum 20KHz Data rate.

When the averaging process of 128-times is performed by using the above A/D converter, the effective bit is increased about 3.36 bit. Therefore, the effective bit of 22bit is used in the circuit[7]. This indicates that ADC has resolution of 1.2μV in the case of 5V input of the input channel.

The stabilization of the power is essential with the consideration needed for the detailed gas concentration measurement. For this reason, the effect of the power noise was minimized through the separation of the digital voltage and analog power in an A/D Converter circuit as the power noise minimization plan. And in the PCB(Printed Circuit Board) design, as shown in Figure 3, each power parts is isolated with cooper pour. Therefore the effect between each power parts was minimized. As shown in Figure 4 which compares the output power in PCB designed with the battery in which the power is stable, the power is stabilized.

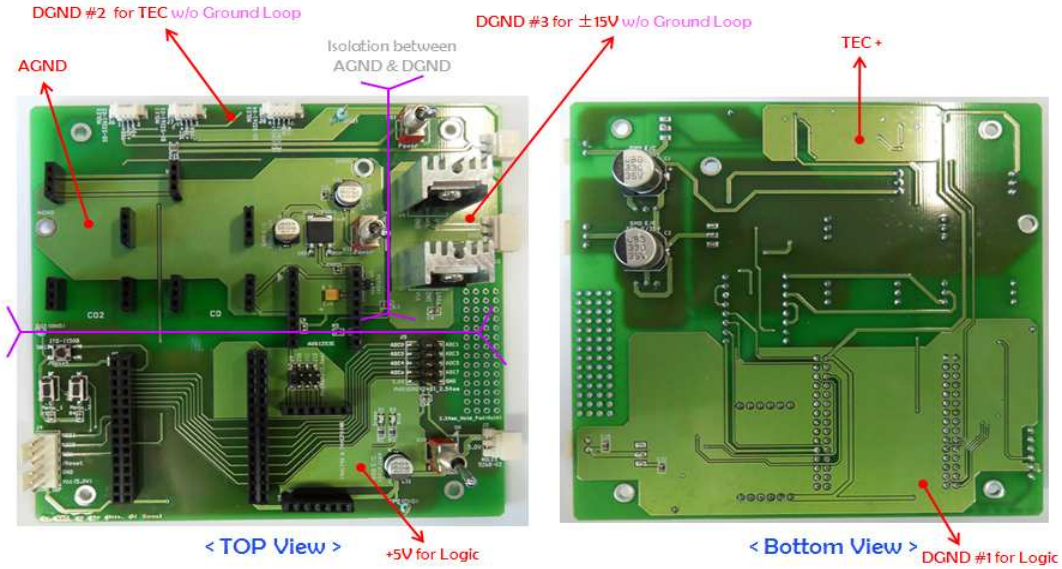

Fig. 3. Power Part Isolation in PCB

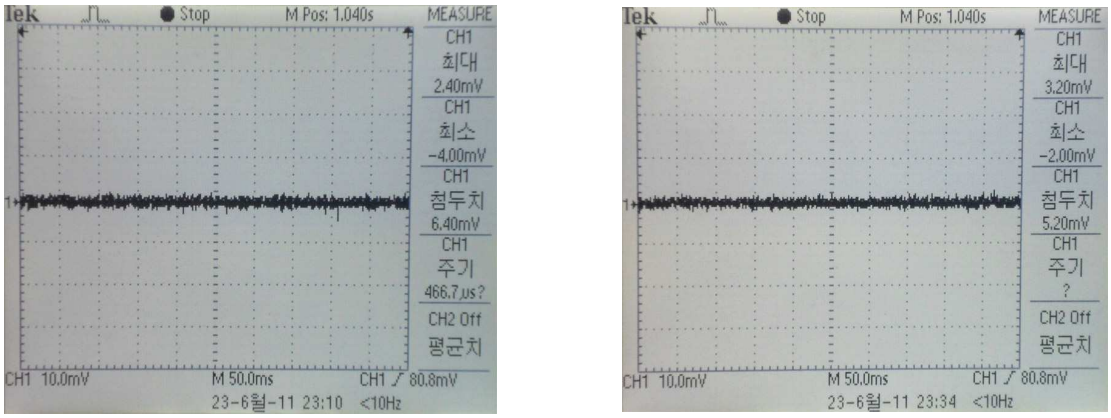

Fig. 4. Battery Power 12V(left) and Designed PCB Power Part 12V(right) in AC mode

Results

Before the concentration of the CO_2 is measured, by using an optical chamber implemented in this research, changing the optical path and measuring the concentration of the CO_2, the resolution of the voltage per the concentration (1ppm) was investigated. Figure 5 is the result of measuring the change of the peak to peak value through the on/off of the emitter sensor while the CO_2 of the constant concentration (94.3ppm) is injected after injecting the N_2,that is the zero gas which doesn't have an effect on the sensor of the detector sensor. Consequently assuming that the CO2 of low concentration has the voltage output linearly, The resolution of a detector circuit is 848μV per 1ppm of CO_2.

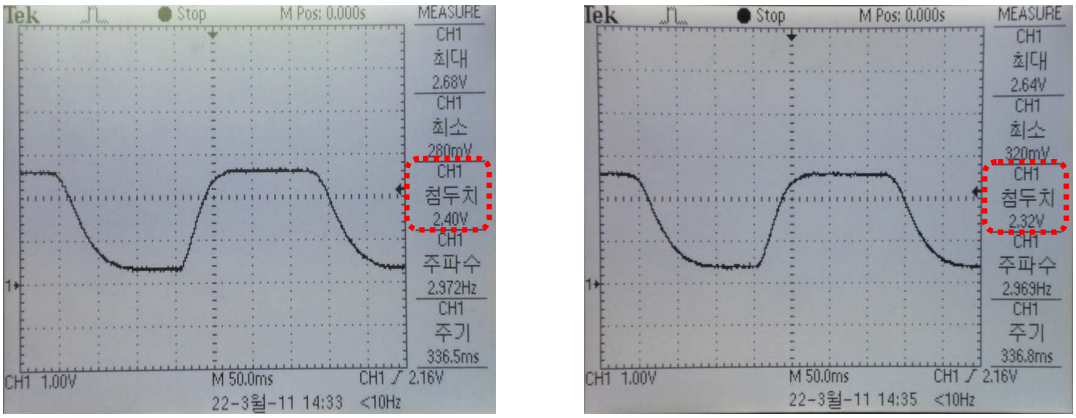

Fig. 5. The voltage peak to peak value of zero gas(Left) and The voltage peak to peak value of CO_2 of the constant concentration(94.3ppm)(right)

In addition, when the output voltage is measured while an optical path is changing by two paths(100mm & 555mm), the ratio of the output of the short path and long path according to the change of the concentration of the CO_2 is shown in Figure 6. This result is expressed with the quadratic formula and log equation in order to be used when the concentration of the CO_2 is measured by using the interpolation method.

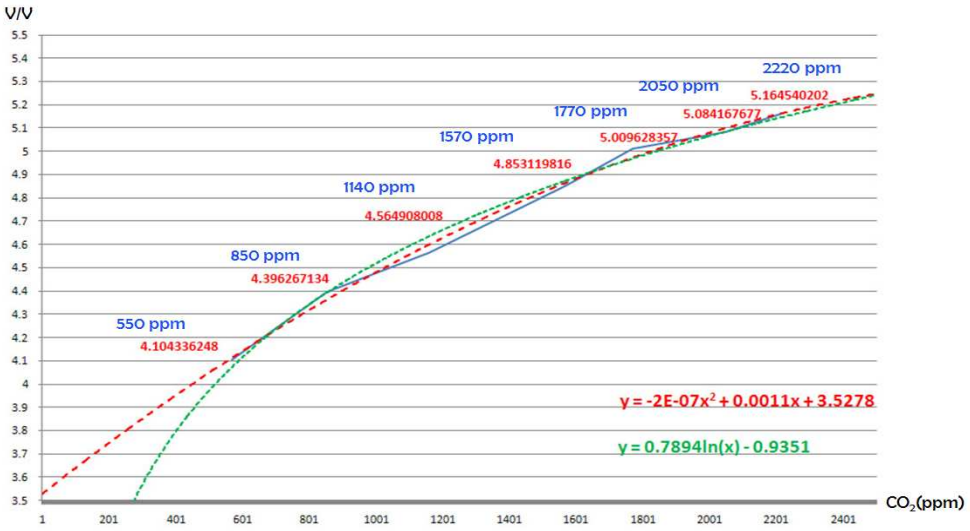

Fig. 6. The output voltage ratio of 2 paths according to CO2 and approximate formula

Conclusion

This research presented a circuit for noise minimization and the sensor selection for NDIR method in addition to a new optical chamber measuring CO_2 and CO simultaneously. And the ratio of the output of the short path and long path according to the change of the concentration of the CO_2 is shown, an approximate formula was made. However it is needed to measure the low concentration of gas(tens of ppb) by amending the approximate formula considering the instability about the temperature of the detector itself. In addition, the experiment for CO, that is the dangerous toxic gas, has to be performed by the special certificate authority and the approximate formula needs to be made like the experimental result of the CO_2.

Acknowledgements

This research was supported by the Seoul R&BD Program (ST090794).

References

[1] Robert Frodl, Thomas Tille, “A high-precision NDIR CO_2 gas sensor for automotive applicat ions”, IEEE Sensors Journal, VOL. 6, NO. 6, pp. 1697, December 2006

[2] Claes G. Mattsson, Goran Thungstrom, Henrik Rodjegard, Kent Bertilsson, Hans-Erik Nilsson , and Hans Martin, “Experimental Evaluation of a Thermopile Detector With SU-8 Membrane in a Carbon Dioxide Meter Setup", IEEE Sensors Journal, Vol. 9, No. 12, pp. 1634, December 2009

[3] W. A. PATTERSON, "Non-Dispersive Types of Infrared Analyzers for Process Control", Applied Spectroscopy, Vol. 6 Issue 5, pp. 17-23, 1951

[4] Terry Barker, Igor Bashmakov, Lenny Bernstein, Jean Bogner, Peter Bosch, Rutu Dave, Ogun lade Davidso, et al., “the IPCC 4th Assessment Report(Mitigation of Climate Change)”, 2007, pp. 3

[5] Bass, M., Van Stryland, E.W., “Handbook of Optic”, vol. 2, McGraw-Hill(1994)

[6] PR43 MID-IR Photoresistor Datasheet, www.roithner-laser.com

[7] ADS1253 Datasheet, www.ti.com