The Development of Cost-Effective Infrared CO_2 Monitor

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Abstract: The measurement of the concentration of CO_2 in air is very important in industry, agriculture, medicine, hygiene, environmental protection and many other fields. But most instruments used or available in the market for CO_2 measurement are analysis instruments with very complicated mechanism and high prices thus limiting their applications. The development of the low-price instrument to measure the concentration of CO_2 in air is therefore urgent. The paper discusses the working principle and the structure of the simple infrared CO_2 monitor based on the infrared technique and an advanced microprocessor. The principle to simplify the hardware of the monitor and to improve its sensitivity and accuracy in the measurement is illustrated. The experimental results have shown that the technique can be adopted to produce the gas composition analyzer at low cost.

Key words: infrared, CO_2, measurement, compensation

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The measurement of the concentration of CO_2 in air is very important in industry, agriculture, medicine and hygiene, environmental protection and many other fields. However, most instruments used to measure the concentration of CO_2 employ very complicated mechanism and have high prices. The aim of this work was to develop a low-cost infrared CO_2 monitor to be applied in the fields where the requirements for the measuring accuracy are not critical.

1 Infrared measurement technique

In general, polyatomic asymmetric molecules, such as H_2O, CO_2, CO, N_2O, *etc* will absorb infrared energy, whereas N_2, O_2 will not.

In the near infrared part of the spectrum, in the range between 2 and 10 μm, a large amount of gases have absorption bands, as shown in Fig. 1. Obviously, in the range between 3.5 and 4.7 μm there is a window with a very strong CO_2 band. The low cost infrared CO_2 monitor works in this band at a wavelength of 4.1 μm.

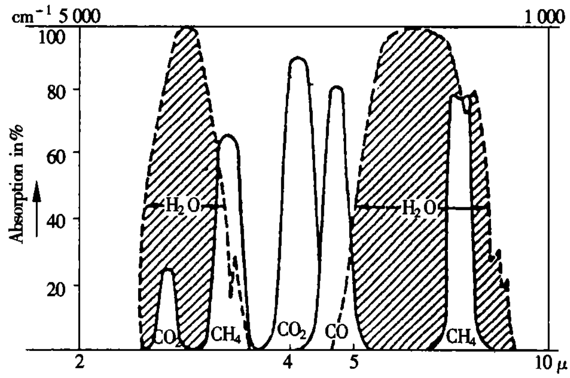

Fig. 1 Infrared spectra between 2 and 10 microns

2 The structure of the low-cost CO_2 monitor

The structure of the low-cost CO_2 monitor is shown in Fig. 2.

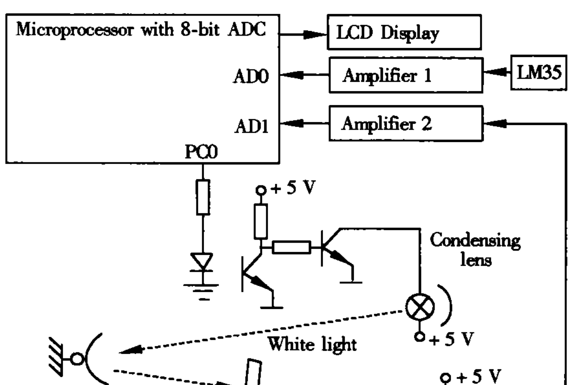

Fig. 2 The structure of the low-cost CO_2 monitor

2.1 Sensor

The sensor consists of a white light source, a mir-

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ror, a filter, and a detector. The light source is an ordinary lamp which emits IR energy as well as visible light. Light from the source is used to illuminate a volume of air where the partial pressure of CO_2 is in equilibrium with the ambient CO_2. The light path of the 4.1 μm is lamp-mirror-filter-detector. Because of the fact that the longer the light path is, the stronger the signal from the detector will be, a concave mirror is used to reflect the light to the detector to strengthen the light path and to concentrate the light. The filter is used to ensure that the infrared light with 4.1 μm wavelength will be projected on the detector. The detector is sensitive to the IR radiation, functioning as a signal detector.

2.2 Adoption of advanced microprocessor to simplify the hardware of the monitor

To simplify the hardware circuits of the monitor, the microprocessor to be used includes an 8-bit A/D converter. Because the microprocessor has 128 bytes internal RAM and 1 k flash program memory on the chip, no external RAM or ROM will be expanded in the system.

The amplifier 2 to be used to amplify CO_2 signals is made up of a low voltage, micropower, high performance quad op-amp LT1079 with slight noise and high gain. The offset current, offset voltage and current noise, slew rate and gain-bandwidth product of the LT1079 are all two to ten times better than those of previous micropower op-amps. Its $1/f$ corner of the voltage noise spectrum is at 0.7 Hz, at least three times lower than that of any other monolithic op-amps, resulting in very good low frequency (0.1～10 Hz) noise performance. Because the LT1079 possesses good characteristics mentioned above, it guarantees the efficient performance of the amplifier.

With the structure and the hardware simplified, the cost of the monitor is much lower than the commercial CO_2 instruments in the market nowadays.

3 The signals and their processing

3.1 The signals from the CO_2 sensor

To compensate the influence of environmental light, the white light source is powered by pulsed current. With the light turned on or off, the signals from the sensor displayed on the screen of the oscilloscope is shown in Fig. 3.

A is the amplitude difference between on and off light waveforms, which represents the signals of a particular CO_2 concentration. The higher the CO_2 concentration is, the smaller the amplitude of the light waveform will be, causing smaller A.

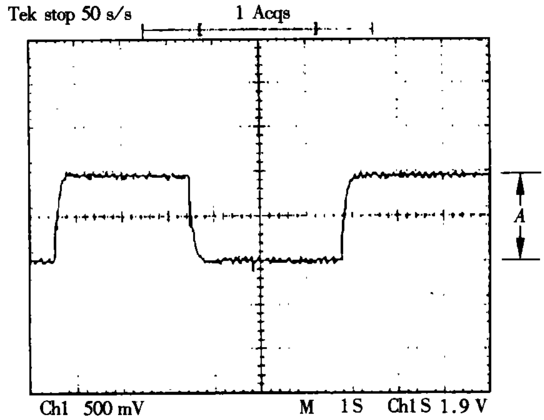

Fig. 3 The waveform of the signal from the sensor

3.2 The principle to improve the sensitivity and accuracy

The intensity of the infrared wavelength is related to the temperature of the light source, which is related to the average current of the light source. To maintain its temperature in an optimum state, the light source is powered by a constant current regulator and it works in the following mode (shown in Fig. 4):

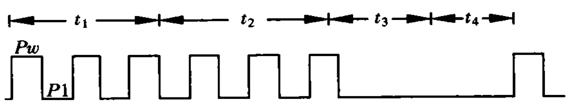

Fig. 4 The working period of the monitor

Pw is the pulse width, during which the light is turned on.

$P1$ is the pulse rest duration, during which the light is turned off.

For time duration 1 the light is turned on, but no sample is taken because the temperature has not reached its stable value.

For time duration 2 the light is turned on and samples are taken at every Pw.

For time duration 3 the light is turned off, but no sample is taken because the temperature of the light source has not reached its stable value like the process of time duration 1.

For time duration 4 the light is turned off and the samples are taken.

Adjusting Pw, $P1$, time 1, time 2, time 3, and time 4 will affect the intensity of the signals because they actually affect the average current of the light source.

3.3 Temperature compensation circuits

The electronic elements on the circuit board of the monitor will emit heat and raise the temperature inside the case of the monitor which will affects the emitting of IR wavelength from the light source. To compensate for its interference, the environmental temperature is sampled and a compensation algorithm is employed. The temperature sensor LM35 is able to give a linear output of 10 mV per degree centigrade, therefore the compensation circuits are very simple and effective.

3.4 The experiment results

The experiments have shown very positive results. With the standard CO_2 tested, whose concentration ranges from 1% to 4%, the errors of the measurement are within ±5%, which can meet the accuracy requirements for many applications.

4 Conclusion

The experimental results have shown that by adopting the technique mentioned above the production of the low-cost infrared CO_2 monitor can be expected. In fact, the technique can be used to measure the concentration of various sorts of gases by changing the filter.

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实用红外 CO_2 测量仪的研制

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[摘要] 空气中二氧化碳浓度的测量在工业、农业、医学、卫生、环境保护和其它许多领域都有非常重要的意义. 目前市售的二氧化碳测量仪表大都属于分析仪表, 它们机理复杂, 价格很高, 难以得到广泛使用, 因此亟需开发一种精度满足要求、价格较低的二氧化碳测量仪器. 本研究给出了用红外传感器和高性能微处理器组成的二氧化碳测试仪的工作原理和简化仪表结构的设计思路, 讨论了提高仪表灵敏度和消除误差的方法. 实验结果表明, 利用这种技术可以制造廉价的气体成分分析仪表.

[关键词] 红外, CO_2, 测量, 补偿

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