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Abstract. Ammonia concentration is the major parameter to evaluate livestock breeding farms atmosphere quality and it also is regarded as the key indicator to describe the production of livestock breeding farms. Based on the oxidation characteristics of ammonia, this paper presented a new intelligent detecting instrument, the intelligent ammonia sensor, for the measurement of ammonia concentration, which used the microcontroller STM8L152 as the key control module. However, the TEDS module, which is useful to self-identification, self-diagnosis and self-calibration of ammonia sensor, is in the flash of the STM8L152 and only if the STM8L152 conveys the warning signal to the alarm module, will the alarm module starts the worker loop.

Keywords： ammonia concentration, livestock breeding farms, intelligent sensor, STM8L152

1 Introduction

Ammonia is a valuable chemical product and material due to its numerous applications in the environmental protection, clinical diagnosis, industrial processes, food processing, and power plants [1-5]. However, it is a kind of colorless gas with a

special odor which is very harmful to human body and livestock. The investigation results show that ammonia can result in serious economic losses by irritating the livestock's respiratory system, which may cause abortion or neonatal malformations such as birth defects, retinitis, and brain damage [6]. In livestock breeding farms，a large amount of ammonia is released through ammonification, a series of metabolic activities that decompose organic nitrogen like manure from livestock [7]. It is performed by bacteria and fungi. The released ammonium ions and gaseous ammonia will be converted to nitrite and nitrate by bacteria [8]. The worldwide ammonia emission resulting from livestock is approximated to be 20–35 Tg/year [9]. Therefore, an effective method for monitoring ammonia is badly needed for the livestock breeding farms environ-mental measurements and control. The numerous efforts have been paid to developing ammonia sensors and many scientific papers have been written concerning ammonia sensors for different domain using several sensing principles. However，there is no adequate research on intelligent ammonia sensor for livestock breeding farms in China, because of following reasons: (I) farmers don't pay attention to the ammonia; (ii) the high cost of ammonia sensor makes it hard to afford; (iii) it does not adapt to the Chinese livestock breeding farms.

With the development of technology and Precision Agriculture, more and more Chinese scientists and research workers pay attention to monitoring ammonia for livestock breeding farms. Among the various sensors, electrochemical sensors have many advantages, such as miniaturization, low cost, rapid response, the inherent high sensitivity, and selectivity [10]. Besides, on-line monitoring has advantages over traditional monitoring approaches on sampling followed by laboratory analysis, because on-line monitoring can collect data anytime and help to know the dynamic information of some element in real-time. But data collection and management, energy efficiency still exist hindering the long-term using of on-line monitoring [11]. Nowadays, foreign corporations still take control of the sensor-market in China. Foreign ammonia sensors are very successful and they are of higher precision and stability than Chinese sensors. But high cost made it impossible for the foreign sensors to be widely used in China. Therefore, electrochemical ammonia sensors which can be used in on-line monitoring for livestock breeding farms are worth developing.

This paper aims to present an intelligent ammonia senor for livestock breeding. With the conditioning circuit, the noise of the ammonia can be reduced, which precision can be guaranteed. The low cost of design makes the long-term monitoring

come true. By using microprocessor and advanced transfer technology, the volume of the ammonia sensor can realize mini-type. As a result, NH_3 concentration and the temperature can be measured.

2 System Design

2.1 Detection Principle

There are two ways，current mode and potentiometric mode，to get the information of ammonia concentration. For intelligent sensors, current mode is applied for lower cost. So, only the detection principles about current mode are introduced here. Ammonia sensors of current mode are based on the principle of potentiostatic polarization method [12] which means response current is measured by excitation voltage .The working principle, structure design and critical fabricating technology of ammonia sensor with three-electrode structure are introduced as follow.

The sensor consists of three electrodes – sensing electrode, negative electrode and reference electrode which are separated by a layer of electrolyte thin film and connected by an external low impedance circuit. The oxidizing reaction of ammonia is on the surface of sensing electrode and the reaction generate an internal current between sensing electrode and negative electrode. The current value is related to ammonia concentration so that the ammonia concentration can be detected while connecting a load resistance to external circuit. The function of reference electrode is keeping electromotive force stable. Besides, no current flows through reference electrode so that each voltage of electrode could be remained stable. In conclusion，three electrodes is made for the intelligent ammonia sensor for livestock breeding farms in China, which was due to various advantage: (I) the intelligent ammonia sensor has a greater measuring range; (ii) it is no different of polarization; (iii) the output could be keep linear. When an appropriate polarization voltage is applied on the sensing electrode and negative electrode, the ammonia can come through the polymer film and participate in the reaction at the negative electrode:

Oxidation at the sensing electrode: $12NH_3+I_2+6H_2O\rightarrow 2IO_3^-+12NH_4^++12e^-$

Reduction at the negative electrode：$3O_2+6H_2O+12e^-\rightarrow 12OH^-$

Overall reaction：$12NH_3+I_2+12H_2O+3O_2\rightarrow 2IO_3^-+12NH_4^++12OH^-$

Based on the Faraday's law Eq. (1), the diffusion current is proportional to the ammonia concentration at a certain temperature when the electrode is selected. That means once we get the measured current, the ammonia concentration can be known [13].

$$i=K\times N\times F\times A\times C_5\times P_m / L \quad (1)$$

In this equation, K represents a constant, while N represents the amount of electrons in the reaction, F represents the Faraday's constant, A represents the cathode area, C_5 represents ammonia partial pressure in the sample, P_m represents the permeability coefficient of film, and L represents thickness of the film [14-15].

Eq. (2) is a mathematical description of an ideal ammonia concentration or ORP electrode behavior. It's an important connection between the electric potential difference and the density of the active material in the electrochemical system:

$$S = K\log_e 1/(1-C) \quad (2)$$

Where：S is output signal, K is the constant, and C is ammonia concentration. Eq. (2) shows that the signals are nonlinear. In most cases, the bias can be ignored and it can be compensated if needed.

In order to monitoring the ammonia concentration of livestock breeding farm, we need to design the circuit and get the information.

2.2 Hardware Implementation

2.2.1System Design

In Fig.1, the ammonia sensor consists of 10 modules and their relations and functions are explained as following.

First of all, the power modules supply electricity to the entire system. Then NH3 concentration can be collected by NH3 detecting probes while TEMP detecting probe is collecting temperature to achieve temperature compensation of NH3 concentration. As NH3 probe need steady current source and TEMP probe need AC current source, excitation signal source consists of 2 modules which provide different sources for two probes. The signal conditioning circuit, which consist of V-I Converter-amplifying circuit and filtering-amplifying circuit, can remove noise and adjust the amplitude of analog signals. The core processor of sensor is MCU STM8L152 with 64 Kbytes of

high-density embedded Flash program and 4 Kbytes of RAM. Moreover, the MCU controls the normal operation of the rest modules.

The TEDS module, which is useful to self-identification, self-diagnosis and self-calibration of ammonia sensor, is in the flash of the MCU. Communication interface module, which is important to communicate with ammonia sensor, is also controlled by the MCU. Only if the MCU convey to alarm module the warning signal will it start the worker loop. Energy management module, which is controlled by the MCU, is designed to make the voltage of the power module stable.

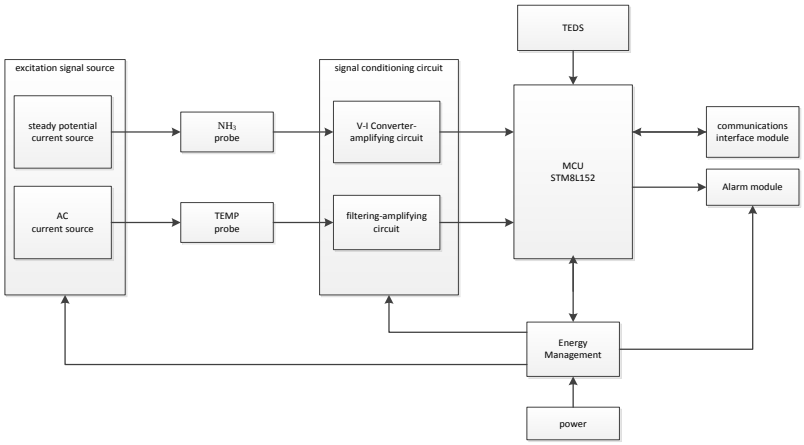

Fig.1. Schematic diagram of intelligent ammonia sensor

2.2.2Circuit Design

The circuit of intelligent ammonia sensor is designed into Integrated Circuit. The ammonia probe adopts the techniques of three-electrode. A very important point of the circuit is the inverse relationship between the circuit noise and response time. In order to get the best precision of the sensor, the optimal between the circuits with loop voltage is less than 10mV. What's more, fast response speed can be guaranteed with least resistance of the circuit. The reference electrode and the induced electrode should be shorted to make sure the sensor is in the state of preparation for work; so the field-effect transistor is used for connecting reference electrode to the ground.

2.3 Description of Software

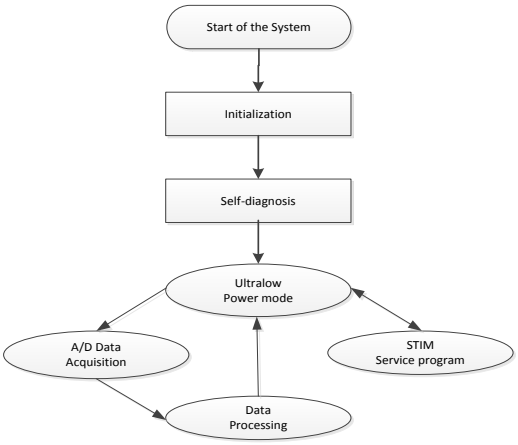

Fig.2. Intelligent ammonia sensor's system program

Intelligent ammonia sensor has modes of working: waiting mode of ultralow power can realize the energy saving; data acquisition mode can get the precise ammonia concentration. With the channel information and calibration parameters in the ferroelectric memory, the style of probe, the serial number and data-structure can be identified. What's more, the self-diagnosis program can also judge whether the intelligent ammonia sensor works normally. Waiting mode of ultralow power aims to improve the system efficiency; the data acquisition need to be triggered by the external signal. In data acquisition mode of STM8L52, the embedded analog-to-digital conversion is good for the simplification of system design. Single conversion mode is adapted to converter the analog data into digital data. In order to guarantee the conversion precision, the average value of 100 conversions is regarded as the measurement result.

System task is triggered by the serial port to receive external trigger signal occurs. And the signal is collected by following pathways: the host computer via RS485 bus, using the microcontroller's serial port to send data acquisition command, the sensor probe under the control of the microcontroller upload the collected data to the microcontroller and the resulting actual measured value of each parameter. If the measured value exceeds the preset alarm value, the alarm means generates an alarm signal. Additionally, the system can also accept serial signals, setting parameters,

sensor calibration.

3 Result and Discussion

3.1 Preparation of the Experiment

The gas of ppm N 5, 10, 25, 50, 75 and 100 were prepared for verify the sensor's reliability and accuracy. The text space is a seal box of constant volume. At the same pressure, the concentration of ammonia can be controlled by changing the discharging time. The required discharging time for standard NH3 concentration results as shown in Table 1. Two pairs of Chinese brand ammonia sensors were prepared for comparative experiment.

Table 1. Required discharging time for standard NH_3 concentration (20℃)

Standard NH_3 concentration (ppm)	0	5	10	25	50	80	100
Time (second)	0	8	16	40	80	128	160

3.2 Comparative experiment with Chinese brand ammonia sensors

At the completely same qualification, we conducted a systematic controlled trials comparing various performance. As can be seen in table 2, the experiment proved that the intelligent ammonia sensor had less reaction time and recovery time. Moreover, the experiment showed that the ammonia sensor had a better accuracy and it can be competent to survey the livestock breeding farms.

3.3 The effects of external stress

A sudden pressure change on the process of sensor detection generates an instant response, and then the peak signal falls immediately. To solve this problem, a restrictor will be placed in front end of the sensor. The experiment showed that the sensor could conquer the

effects of external stress completely. And the specific data is simple so that it can be shown from table 2.

Table 2. experiment of standard NH_3 concentration (20℃)

Standard NH_3 concentration (ppm)	0	5	10	25	50	80	110
Experiment value (mV)	5	63	146	295	591	947	1106
Comparative value 1 (ppm)	0	7.88	11.88	26.25	49.9	74.68	108.13
Comparative value 2 (ppm)	0.08	3.3	7.6	21.03	58.13	73.31	91.25

3.4 Calibration of the ammonia sensor

The demarcation curve can be obtained from Table 2, shown as Fig. 3. Least square m ethod is used for curve fitting in this paper. The fitting formula is Eq.3.

$$y=0.083(x-5) \quad (3)$$

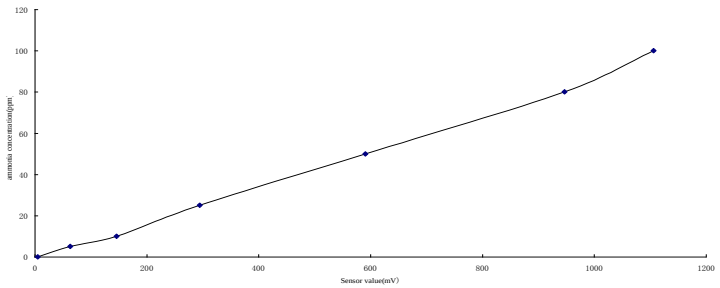

Fig.3. Output character of intelligent ammonia sensor on 20℃

3.5 Characterization and Validation of the intelligent ammonia sensor

From table 3 we can get the conclusion that the accuracy of the intelligent ammonia sensor is less than 5%, which means the intelligent ammonia sensor can be applied to monitor the ammonia concentration of livestock breeding farms because the accuracy of the intelligent ammonia sensor is satisfied for the livestock breeding. So compensation calculation and calibration calculation are effective to get actual values.

Table 3. *Characterization and Validation of the intelligent ammonia sensor* (20℃)

Standard NH_3 concentration (ppm)	0	5	10	25	50	80	100
sensor value (ppm)	0	6	9	27	48	83	104

4 Conclusion

In this article, we carefully studied the detection methods for measuring the ammonia concentration, designed a low-power, low noise, high speed, intelligent ammonia measuring device.

(1) The system chose STM8L152 microcontroller as the core of the detection control unit, its rich pin function and the built in functional unit simplify the system's design, which improved stability and anti-jamming capability of the system.

(2) The system choose single-chip PWM as output control, and other functional units selected low-power devices for designing, which effectively reduced the system power consumption. The overall average power consumption of the system is only 0.03W.

(3) As can be seen from the experimental data of the system repeatability tests and linearity tests, the system has good linear consistency no matter how low or high the concentrations of ammonia is.

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