Studying and Realizing the Smart Device for Measuring and Monitoring Ammonia Concetration, Applying for NPK Fertilizer Industry

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***Abstract*— The paper presents an approach for design and realization of the smart device for measuring and monitoring ammonia concentration, this can be applied to NPK fertilizer production plant. A hardware has been developed based on the ATMEGA328P microcontroller in order to perform data collection function from the ammonia sensor MQ135. We are also built algorithms for signal processing and warning according to different thresholds in this microcontroller (MCU). The collected data will be transmitted to the computer via wireless communication. In addition, an interface software is designed on computers to collect and monitor data from sensors. Our device allows to measure ammonia concentration up to 300ppm. Tests are implemented at the laboratory and the NPK factory of Lamthao fertilizers and chemicals joint stock company (Lafchemco) that demonstrate positive results.**

Keywords*— *ammonia concentration, MCU, smart device, wireless communication

I. INTRODUCTION

NPK fertilizer is a composite fertilizer containing at least 2 in 3 components: N (protein), P (phosphate), K (Kali). This fertilizer provides many important nutrients, works to make plants more lush, grow height and volume of leaf stems, form fruit, sprout buds ...

Nowadays, the mainly used NPK fertilizer production technology is high tower technology. This is a modern fertilizer production technology, applying in many countries around the world. Raw materials for fertilizer production include: $(NH_2)_2CO$, $NH_4H_2PO_4$, KNO_3, $CaCO_3$ and other trace elements mixed together. It will be taken to NPK granulation tower then. At this time, heating and maintaining the materials at a certain temperature, the main material is Urea $(NH_2)_2CO$) will melt and mix with other materials and form a almost homogeneous fluid. After that, this fluid will be automatically discharged to a centrifugal granulator. It will form fluid particles in free fall in the center of the tower, and are blown from the bottom up by the ultra-high-speed blower system to reduce the rate of falling and drying before the particles fall the separator sieve. The dry and round particles will slowly fall to the separator sieve of product classification, the required particles will be forwarded to the system of membrane spraying anti-clumping.

Accompanying with the production of NPK fertilizer is the problem of generating poison emissions into the natural environment and the working environment at the factory, seriously affecting the environment and human health. In the poison gases generated, ammonia (NH_3) is a gas that causes many harms to human health.

There are many studies related to this field, including studies focusing on developing sensors to measure ammonia concentrations as [1]. In this study, the authors developed a sensor base on conductive polymer, this showed a good sensing response that increases considerably with the addition of N-GQDs. Other studies focus on designing and optimizing sensors based on titanium oxide nanowire for measuring the gas concentration [2]. In [3], they studied the operating principle of the sensor, that is based on the change in work function of the sensitive film due to gas adsorption on its surface. This sensor is used for measuring ammonia concentration in room temperature.

The application of microcontrollers and embedded computers to ammonia measuring and monitoring devices has also been carried out in many parts of the world. It makes these devices more intelligent and flexible, and that can mention to the study of measuring many gases in the farm using Arduino and embedded microcontroller systems [4].

From the above analysis, we enounce the requirement about studying and realizing a smart device in order to measure and monitor ammonia concentration, applying for NPK fertilizer industry using microcontroller, enabling smart alarms with multiple thresholds, allowing wireless connection.

II. NH_3 CONCENTRATION MEASUREMENT METHOD

A. Electrochemical method

This method works by allowing gas to diffuses through the porous membrane to the electrode. The oxidized or reduced electrode leads to the amount of generated electricity determined by the oxidized gas at the electrode, thereby determining the gas concentration . This sensor using in many different environments such as oil refineries, gas turbines, chemical plants,…

Advantages:

- High stability, fast speed.
- Less maintenance.

Disadvantages:

- Sensors are subjected to corrosion or chemical contamination.
- Lifespan: 1-2 years.

B. Semiconductor method

The principle works based on chemical reactions when the sensor is in direct contact with the gas, the resistor in the sensor is reduced in proportion to the exposure gas concentration. Resistors in semiconductor sensors are made mainly from tin dioxide (about 50 kΩ in air, can be reduced to about 3.5 kΩ when there is 1% methane). Semiconductor sensors are often used to detect hydrogen, oxygen, alcohol vapor and toxic gases such as carbon monoxide [5].

Advantages:

- High stability, fast speed.
- Less maintenance.
- Low price.

Disadvantages:

- Sensors are subjected to corrosion or chemical contamination.

C. *Using MQ135 sensor to determine NH_3 concentration*

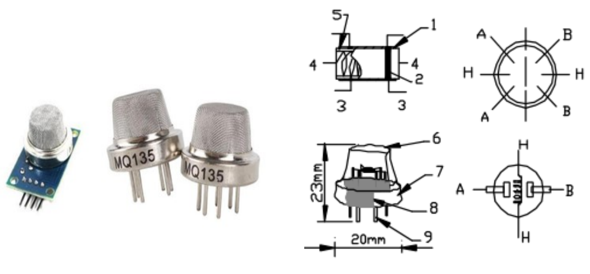
1) *MQ135 sensor:*

MQ135 is a gas sensor manufactured by Hanwei Sensor from Taiwan which is a sensor based on the principle of conductivity (semiconductor sensor). The material of the sensor is tin oxide (SnO_2) with low electrical conductivity in clean air.

The principle works based on the change in conductivity of thin- membrane semiconductors when absorbing gas on the surface at high temperatures. When the sensor detects gas, the resistor of the tin oxide layer decreases in proportion to the gas concentration. This sensor is mainly used to measure toxic gases such as: NOx, NH_3, CO,....

Specifications of MQ135:

- Voltage of the burner: $5V \pm 0.1 AC / DC$;
- Load resistor: Changeable (2kΩ-47kΩ);
- The resistor of the heating unit: $33\Omega \pm 5\%$;
- The detection range: 10-300 ppm NH_3.



a) MQ135 Sensor Module *b) Structure of MQ135 Sensor*

Fig. 1. MQ135 sensor.

The description of the signal pin reference of the MQ135 sensor structure is shown in Table 1.

TABLE I. REFERENCE FOR STRUCTURE OF MQ125 SENSOR

No.	Name	Material
1	Thin- membrane	SnO_2
2	Electrode	Au
3	Wire	Pt
4	Incandescent	Ni – Cr alloy
5	Cylindrical block	Al_2O_3
6	Protective nets	Stainless steel
7	Clamp ring	Ni copper plating
8	Plastic soles	Bakelite
9	PIN pins	Ni copper plating

The sensor needs to be supplied with two voltage sources: the calcined voltage (V_H) and the supply voltage (V_C). The source used to heat the burner, V_C used to generate voltage (V_{out}) on the load resistor (R_L). Two sources V_C and V_H can use the same power circuit to ensure sensor performance. To use the sensor with the best performance, the R_L appropriate value to choose is $20k\Omega$ (adjustment range from $20k\Omega$ to $47k\Omega$).

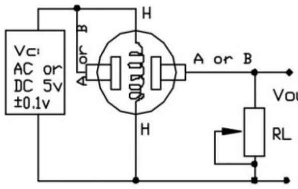


Fig. 2. Principle diagram.

Considering environmental conditions: temperature $20^o C$, humidity 65%, concentration O_2 21% and load resistor $R_L = 20k\Omega$.

The sensor capacity can be calculated:

$$P_S = V_C^{\,2} \frac{R_S}{(R_S + R_L)^2} \qquad (1)$$

The sensor resistor can be calculated:

$$R_S = \left(\frac{V_C}{V_{out}} - 1 \right) R_L \qquad (2)$$

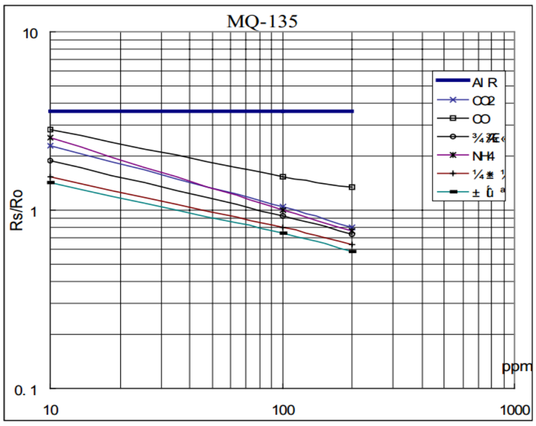


Fig. 3. Graph of characteristics of MQ135.

In Fig. 2, R_L resistor combines with resistor of sensor (R_{AB}) to form a voltage circuit. The voltage on R_L is proportional to the gas concentration received by the sensor.

Where:

- R_0 is the volume of the sensor resistor at 100ppm NH_3.
- R_S is the value of the sensor resistor at other conditions of the air.

The MQ135 sensor is affected by temperature and humidity, so when surveyed, for each measured value, the temperature and humidity of the corresponding environment should be determined.

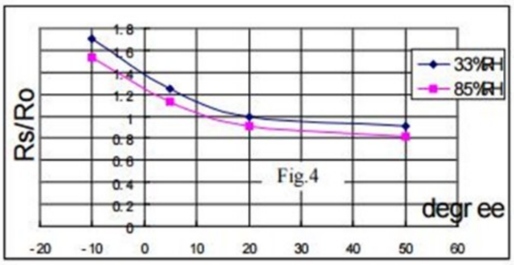


Fig. 4. Effect of temperature and humidity to MQ135.

2) Develop NH_3 equation for MQ135

The first step is to find the resistor value R_0. From Fig. 5, we can see that the value $\frac{R_S}{R_0}$ is constant with the air (dark blue line), when the sensor operates in the fresh air, the value of $\frac{R_S}{R_0} \approx 3.6 \Rightarrow R_0 \approx \frac{R_S}{3.6}$ (3)

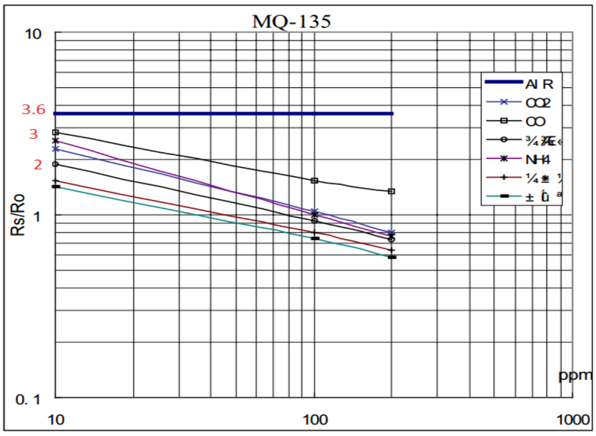


Fig. 5. Find R_0.

Set the sensor at a room with conditions: clean air, temperature 20^oC, humidity 65%, O_2 21% and $R_L = 20k\Omega$. We have:

$$R_S = \left(\frac{V_C}{V_{out}} - 1\right)R_L \qquad (4)$$

Replace (4) into (3):

$$R_0 = \frac{\left(\frac{V_C}{V_{out}} - 1\right)R_L}{3.6} \qquad (5)$$

With V_C = 5V and $R_L = 20k\Omega$, V_{out} is the output voltage of the sensor. We used the program on Arduino IDE for determining the R_0. The result is show in Fig. 6.

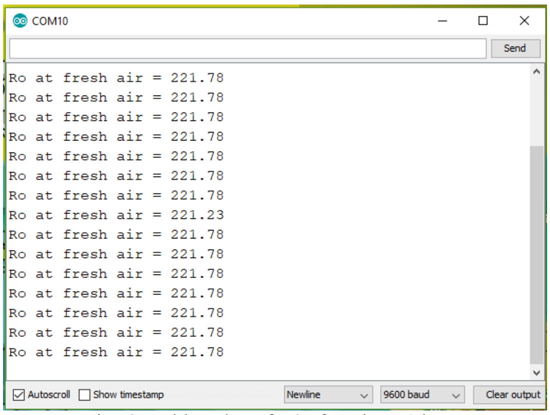


Fig. 6. Stable value of R0 after about 1 hour.

After waiting for a stable R_0 value, we conclude $R_0 = 222k\Omega$. For next step, we find the relation expression between ppm and $\frac{R_S}{R_0}$.

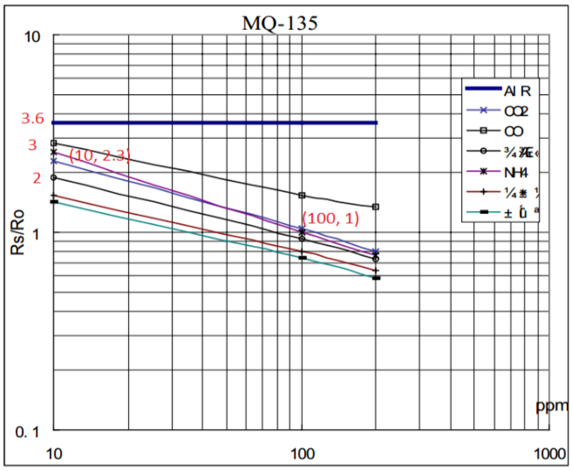


Fig. 7. Find the relationship between ppm and $\frac{R_S}{R_0}$.

The relation between $Log(ppm)$ and $Log\left(\frac{R_S}{R_0}\right)$ is a linear relationship that can be represented by the expression:

$$Log(y) = m * Log(x) + b \qquad (6)$$

In which $y = \frac{R_S}{R_0}$ and $x = ppm$. By visualizing through Fig. 8, we can see the graph going through 2 points $(10, 2.3)$ and $(100, 1)$, then, entering (6):

$$\Rightarrow \begin{cases} Log(y_1) = m * Log(x_1) + b \\ Log(y_2) = m * Log(x_2) + b \end{cases}$$

$$\Leftrightarrow \begin{cases} m = -0.362 \\ b = 0.724 \end{cases}$$

$$\Rightarrow ppm = 10^{\left\{\frac{\mathrm{Log}\left(\frac{R_S}{R_0}\right)-b}{m}\right\}} \quad (7)$$

III. DESIGN EQUIPMENT FOR MEASURING AND MONITORING NH_3 CONCENTRATION

A. *Hardware design*

The schema block of hardware is presented in Fig. 8.

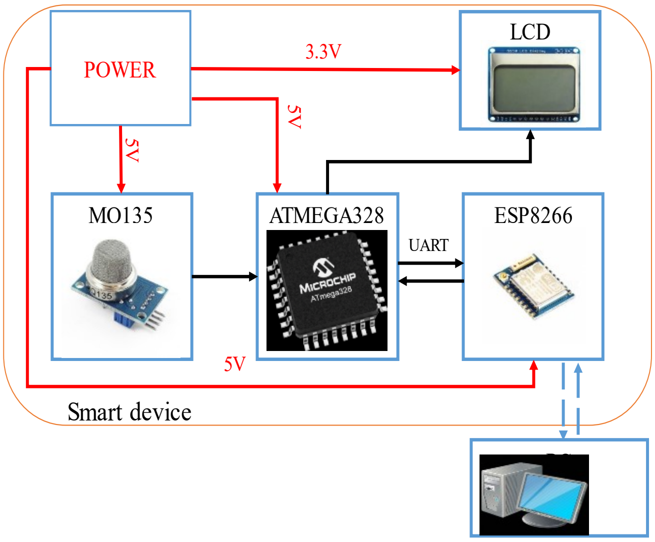


Fig. 8. Block diagram of the device.

1) *Source power:* using 2 ICs:

- LM1117 creates 3.3V power feeding ESP8266 and LCD.
- LM1117 5V power supply feeding MQ135, ATMEGA328P.

2) *ATMEGA328P microcontroller:*

ATmega328P has a full name: ATmega328P-PU, belongs to MegaAVR family, is a 8 bits microcontroller, based on RISC architecture, 32KB ISP flash memory program, can write erase thousands of times, 1KB EEPROM, and 2KB SRAM.

With 23 pins can be used for I/O connections, 32 registers, 3 timer/counter programmable, internal and external interrupts (2 commands on an interrupt vector), transfer protocol USART, SPI, I2C serial communication. In addition, an 8-bit analog digital converter (ADC) can be used, programmable watchdog timer, operates with 5 power modes, can use up to 6 pulse width modulation channels (PWM).

3) *Module WiFi:*

ESP8266 is a microprocessor designed by Espressif System. Features of ESP8266 are built-in Wi-Fi. There are many types of boards designed using ESP8266 processor. The difference of board types is the number of GPIOs (GPIOs are the ports used for input or output).

4) *LCD screen:* Nokia LCD 5110

The technical parameters of LCD screen is presented in Table II.

TABLE II. LCD 5110 SPECIFICATIONS

Operating voltage	2.7 – 3.3VDC
Current consumption	6mA
Screen size	84x48 pixel monochrome
Communication standard	SPI
Processor	Philips PCD8544
Backlight	Blue

B. *Software design*

1) *Software for microcontroller*

a) *Software for ESP8266:*

The flow chart of the sorftware program in ESP8266 is presented in Fig. 9. We used the C/C ++ language, Arduino as ISP compiler.

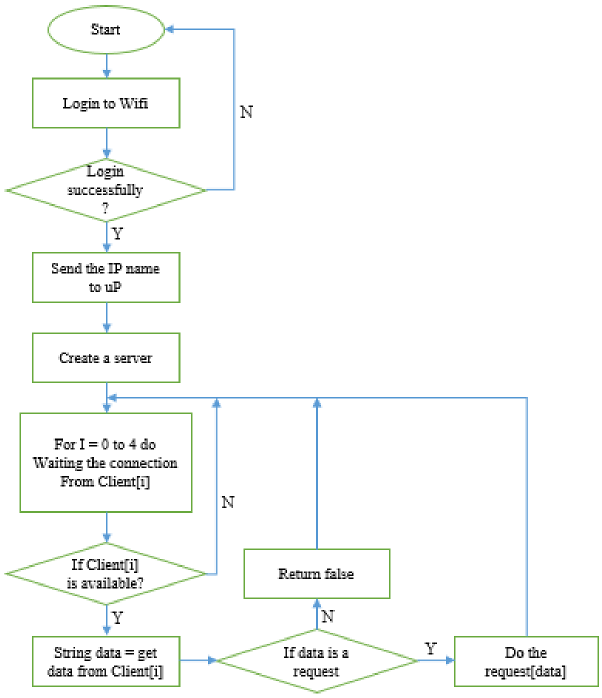


Fig. 9. Algorithm flowchart on ESP8266.

b) *Software for ATMEGA328P:*

The flow chart of the software program in MCU ATMEGA328P is presented in Fig. 10. We used use C/C ++ language, Arduino as ISP compiler.

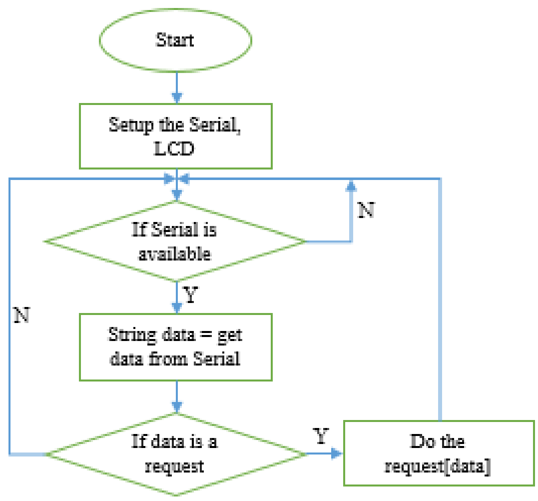


Fig. 10. Algorithm flowchart on ATMEGA328P.

2) Software on the computer:

We have been developed a software program based on the Visual Studio C #, the task of this software is:

- Connect to smart device.
- Display and warning measurement results on observation graphs.
- Store the measurement results into the database.

IV. EXPERIMENTAL RESULTS

The central microcontroller of the measuring device performs the function of reading and processing the measured data from the NH_3 gas concentration sensor. The data is then taken to the Communication Module. The device hardware is shown in Fig. 11.

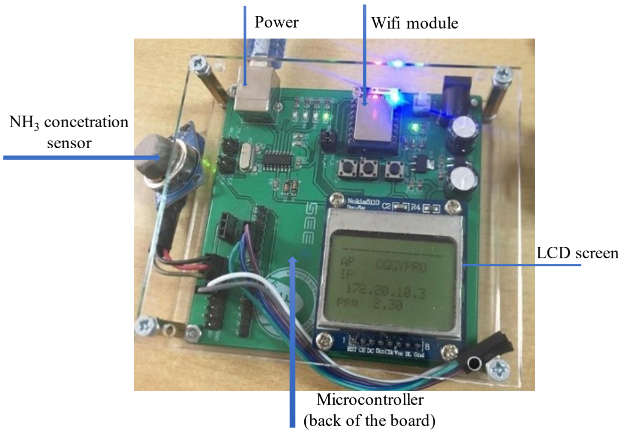


Fig. 11. Hardware board.

The communication part from this measurement device to the computer is used via the Wi-Fi module ESP8266.

The Graphical User Interface (GUI) is developed base on Visual Studio C # gives the results obtained from the device shown in Fig. 12.

The evolution of NH_3 concentration in the laboratory has fluctuated slightly. Our initial calibration is based on the characteristic curve provided by the sensor characteristic. Surely we need to calibrate this device in a professional calibration unit.

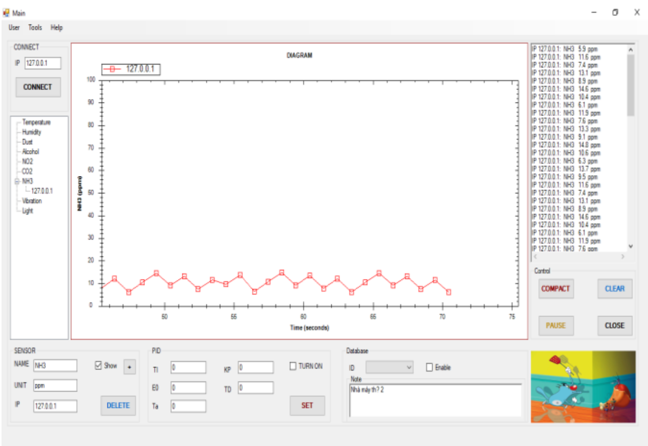


Fig. 12. Results observed in the laboratory.

We also bring this device to test the ambient air environment at NPK company- Lafchemco, Vietnam. The experimental result is presented in Fig. 13. The difference in measurement results in this field can be seen with the results in Fig. 13. The concentration of NH_3 gas has doubled compared to the case in the laboratory. However, when compared to the Vietnamese standard, the NH_3 concentration in the factory is still within acceptable levels. We believe that the measurement and monitoring of NH_3 concentration in the plant should be carried out continuously and permanently to ensure the measurement and warning of exceeding the permissible threshold of NH_3 gas concentration. In case the measured value exceeds the allowable thresholds, the software will issue warning messages to the user.

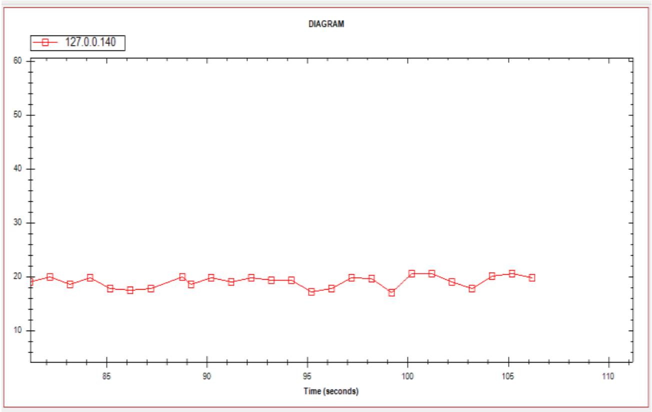


Fig. 13. Measurement results at Lafchemco.

V. CONCLUSION

We have successfully designed and fabricated ammonia concentration measuring and monitoring device with built-in Atmega328 microcontroller. The device works well in the laboratory and in real environment with measuring range and monitoring from 10-300ppm.

The algorithms developed in the device allow them to alert smartly, implemented the communication protocol to the monitoring computer. Surely, we will continue testing and calibrate the device in the future. In addition, the development of connecting devices in IoT (Internet of Things) applications is also the next direction of this study.

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