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Design and Development of Co, Co_2, Ch_4, and Nh_3 Gas Detection Equipment Based On Iot

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Abstract

One of the occupational safety and health in chemical laboratories is maintaining air conditions so that they are not contaminated by toxic gases. To optimize it, an IoT-based CO, CO_2, CH_4, and NH_3 gas measuring instrument is designed using a Raspberry Pi 3, MQ-135 sensor, MQ-7 sensor, MQ-4 sensor, DHT22 sensor, buzzer, and LCD. The measurement data will be displayed on the Node-RED UI. The result is that the instrument can detect levels of CO, CO_2, CH_4, and NH_3 gases, can measure room temperature and humidity, and also provide a hazard warning. The measurement results are the average measurements on 25 ml of liquid ammonia with a concentration of 25%. 50%, 75%, and 100% obtained values of 0.22 ppm, 0.50 ppm, 1.04 ppm, and 3.95 ppm, while at 25 ml of methanol with concentrations of 25%, 50%, 75%, and 100% obtained an average of 0.21 ppm, 1.97 ppm, 2.45 ppm, and 4.49 ppm. Another measurement result is the average measurement of CO and CO_2 gas levels are 7.06 ppm and 5.05 ppm. The temperature and humidity sensor have an average measurement of 29.0°C and 70.7%. There is no delay in sending data from the Raspberry Pi to the UI Node-RED.

Keywords— occupational safety and health, gas detection, raspberry pi, node-red user interface, internet of things

Introduction

Occupational safety and health are very important when someone carries out a job. With this, a person can avoid accidents at work. One of the occupational safety and health that needs to be achieved is maintaining air conditions so that they are not contaminated by toxic gases, especially in chemical laboratories. Toxic gases are gases that can cause damage to living tissue, the central nervous system, or in extreme cases when ingested, inhaled, or absorbed by the skin or eyes [1]. At very high concentrations, toxic gases can cause loss of consciousness, weakness, difficulty breathing, and even death. In this research, the chemical laboratory in Indonesian Nuclear Technology Polytechnic-BRIN was used as a place of measurement, where in this laboratory there were several toxic gases, such as carbon monoxide (CO), carbon dioxide gas (CO2), methane gas (CH4), and ammonia gas (NH3). These gases can cause health problems or may cause death if continuously enter the body. Therefore, to avoid these work accidents, auxiliary instruments are needed to detect them and identify the concentrations of these gases in the air [2].

To optimize occupational safety and health in the chemical laboratory of the Indonesian Nuclear Technology Polytechnic-BRIN, an IoT-based CO, CO2, CH4, and NH3 gas measuring instrument is designed using a Raspberry Pi 3, MQ-135 sensor, MQ-7 sensor, MQ-4 sensor, DHT22 sensor, buzzer, and LCD. The measurement data will be displayed on the Node-RED UI. The results of this instrument are expected to minimize the possibility of work accidents when carrying out practical and research activities in chemical laboratories.

Previous Researches

In previous studies, conducted by Widodo et al. in 2017, measurements of CO, CO2, and CH4 gas levels were carried out in a closed room using an MQ-135 gas sensor and an ATMEGA 8535 microcontroller with an LCD, LED indicator, and a blower to neutralize clean air from harmful pollutant gases [3]. In 2017, research conducted by Srinivas and Kumar, a gas leak detection device was designed using the Arduino Uno R3 microcontroller based on the Internet of things which intended to avoid industrial accidents, monitor harmful gases, and notify the workers of the industry by SMS in case any gas leakage is occurred in any sector of the industry [4]. In 2018, Alkandari and Moein presented an implementation of a monitoring system for air quality in Kuwait using Raspberry PI to detect dangerous gases such as carbon monoxide, nitrogen dioxide, and other gases [5]. In 2019, a study conducted by Rajalakshmi, R. and J. Vidhya, a prototype toxic environmental monitoring system was designed using an ATMEGA328P microcontroller with measurement parameters of hydrogen, carbon monoxide, methane, and combustible gases in hazardous places, such as fireplaces, chemical industries, and landfills. Each gas level is measured using gas sensors and the measurement results are sent to a cloud server [6]. In 2021, Irawan et al. designed a real-time system monitoring and analysis-based internet of things technology in measuring outdoor air quality due to peatland fires which cause the presence of thick smoke every year in Riau and disrupt human activities using the DHT11 sensor, MQ135 gas sensor, Arduino Uno, and Raspberry Pi [7]. Then in 2022, Veerani et al. designed an air quality monitoring system using an MQ135 sensor to measure air quality and an MQ7 sensor to measure carbon monoxide with IoT platforms [8].

Method

This research begins with a literature study. Then do the gas detector system design. The design of this system is divided into three stages, hardware design, software design, and Node-RED user interface (UI) design.

Hardware Design

A toolbox design is made with a length of 14 cm, a width of 10 cm, and a height of 8 cm using CorelDRAW X7 for each side of the box for a gas detector, which then this design file will be inputted into the laser cutting machine. The circuit design of this system is shown in Figure 1.

Based on the design in Figure 1, there are three types of gas sensors, there is the MQ-135 sensor used to detect NH3 gas and CO2 gas, the MQ-7 sensor to detect CO gas, and the MQ-4 sensor to detect CH4 gas [9][10][11]. Each gas sensor is given an input voltage of 5V. The analog pins of the three gas sensors are connected to the level converter to reduce the voltage from 5V to 3.3V. This voltage drop is because the MCP3008 uses a reference voltage of 3.3V. The output of the Level converter is then Connected to MCP3008 to convert analog gas sensor data. The MCP3008 device is a 10-bit analog to digital (A/D) converter with an onboard sample and holds circuitry [12]. The microcontroller used in this study is Raspberry Pi 3 as a control device. The Raspberry Pi 3 is a single-board computer running on a Broadcom BCM2837 64bit ARMv7 Quad Core Processor at a maximum frequency of 1.2GHz with 40 pin GPIO, 1 GB RAM, onboard BCM43143 Wi-Fi module, and Ethernet port [13]. This design also uses a DHT22 sensor to detect room temperature and humidity, an LCD to display sensor measurements, and a buzzer to provide a warning sign if the sensor reading exceeds or is less than the threshold limit value.

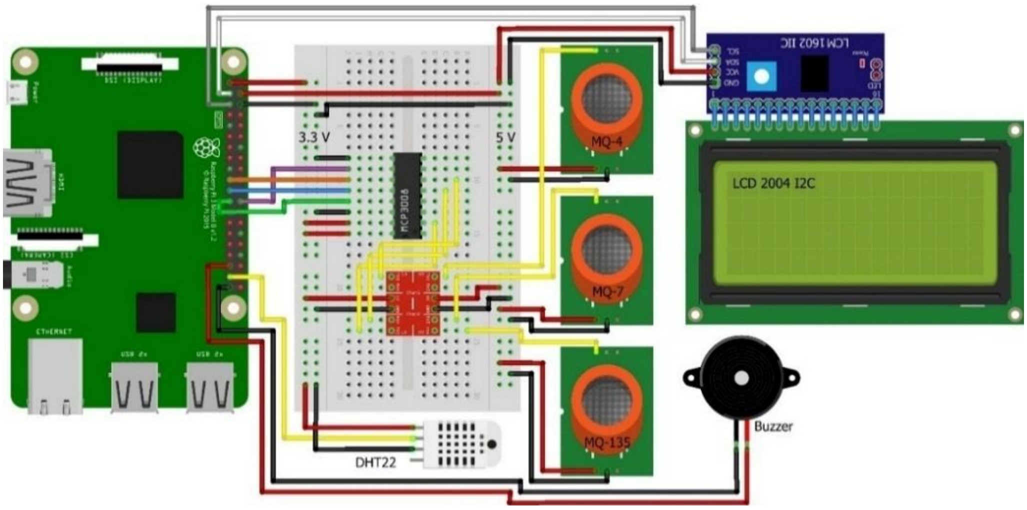

Figure. 1. *Gas detector circuit design*

Software Design

Program design is done by importing libraries, declaring pins, making programs for reading gas, temperature, and humidity sensors, making data display programs on the LCD and Node-RED UI, and also making buzzer-sounding programs. The stages of the program are shown in Figure 2.

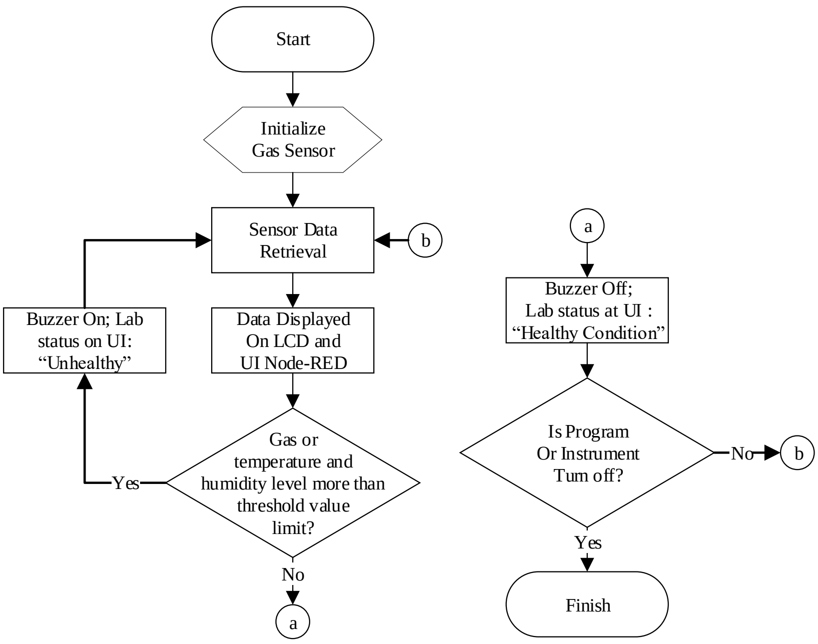

Figure. 2. The stage of program

User Interface Design

In designing the user interface, a browser-based Node-RED application is used. Node-RED is a visual programming environment conceived for programming the IoT [14]. This application is browser-based in the form of a flow consisting of several interconnected nodes, where each node has its function. The flow program used can be seen in Figure 3.

After the program flow is complete, then the node settings are carried out. On the MQTT In server node, broker settings are carried out. After that, press the deploy button and run the user interface by typing http://localhost:1880/ui.

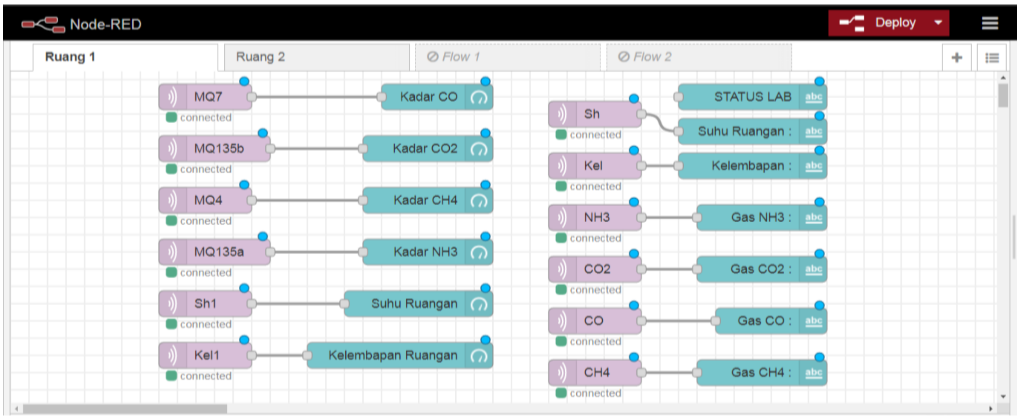

Figure. 3. *UI flow program*

Instrument Test

After the system design is complete, the next step is instrument testing. There are four kinds of tests, namely temperature and humidity sensor testing, gas sensor testing, buzzer testing, and time delay testing. In the first test, the room temperature and humidity were measured by placing the sensor in the chemical laboratory. The tests continue by measuring the gas content produced from chemicals and combustion products and also testing the sensor limitations in measuring gas. Furthermore, the buzzer is sounded by increasing the temperature and humidity and putting the chemicals and combustion gases closer to the gas sensor. In the last test, a comparison was made between the time of sending data with the time of receiving data.

Result and discussion

Hardware Design Result

The results of the design and manufacture of CO, CO2, CH4, and NH3 gas detectors are shown in Figure 4, where on the front side there is an LCD as a data viewer, on the right side there is a gas sensor, and on the left side there is a room temperature and humidity sensor.

(a) (b) (c)

Figure. 4. *Hardware design result (a) front side (b) right side (c) left side*

Node-RED User Interface Results

The results of the Node-RED user interface are shown in Figure 5, where in this UI there is a gauge to display CO levels, CO2 levels, NH3 levels, CH4 levels, room temperature, and room humidity, as well as laboratory status. indicating laboratory conditions.

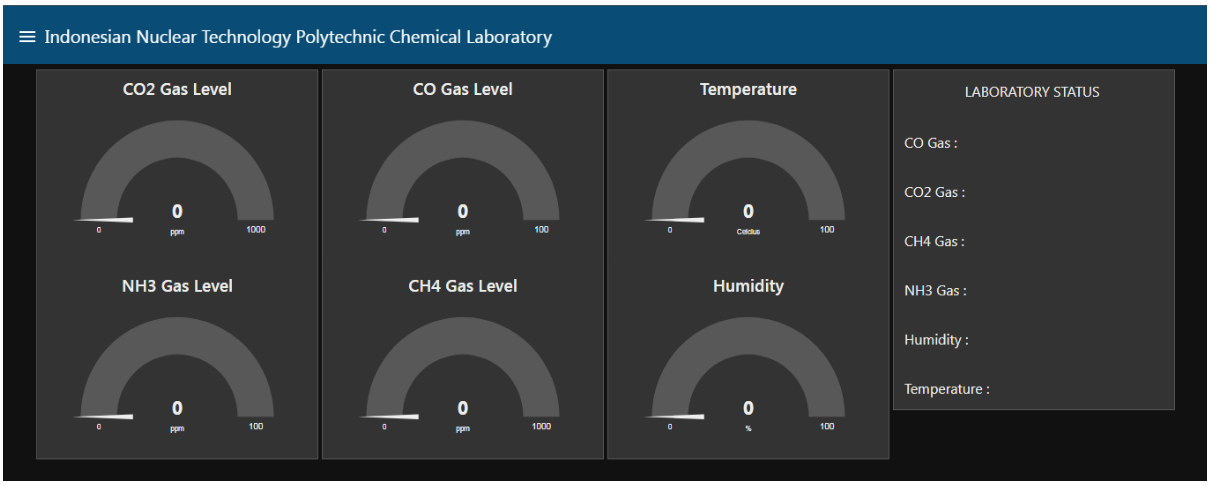

Figure. 5. *Node-RED User Interface*

Temperature and Humidity Sensor Measurement Results

Results, the average laboratory temperature and humidity are 29.0°C and 70.7%, respectively. From these results, laboratory humidity exceeds the limit value stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 1077/MENKES/PER/V/2011, which is 60%. [15]

Table 1. *Temperature and Humidity Sensor Measurement*

Temperature (°C)	Humidity (%)
29.0	70.9
28.9	70.9
29.0	70.8
29.0	70.6
29.0	70.3

Table 2. *CO_2 Sensor Measurement Results*

Minute	CO_2 Concentration (ppm)
1	4.71
2	4.47
3	5.24
4	4.97
5	5.53
6	4.25
7	6.88
8	4.25
9	5.24
10	4.97
Average	5.05

CO2 Sensor Measurement Results

In testing the CO_2 gas sensor, gas measurements were carried out by burning mosquito coils. Then the gas created is measured for 10 minutes. Measurement of the sensor limit is also carried out at a measurement distance of 10 cm to 60 cm. The test results are shown in Table 2 and Table 3.

Table 3. *CO_2 Sensor Distance Limit Test*

Distance (cm)	CO_2 Concentration (ppm)
10	0.90
20	0.64
30	0.20
40	0.11
50	0.03

Table 4. *CO Sensor Measurement Results*

Minute	CO Concentration (ppm)
1	6.38
2	5.92
3	7.42
4	6.87
5	8.00
6	5.29
7	10.92
8	5.49
9	7.42
10	6.87
Average	7.06

Based on the results of these measurements, it is known that the gas content from the burning of mosquito coils has an average CO_2 measurement of 5.05 ppm and the sensor has a distance limit of measuring CO_2 gas levels at a distance of more than 50 cm.

CO Sensor Measurement Results

CO gas sensor testing is carried out by measuring gas by burning mosquito coils. Then the gas created is measured for 10 minutes. Testing of the sensor reading distance limit was also carried out at a measurement distance of 10 cm to 40 cm. The test results can be seen in Table 4 and Table 5.

Table 5. *CO Sensor Distance Limit Test*

Distance (cm)	CO Concentration (ppm)
10	0.62
20	0.38
30	0.08
40	0.03
50	0.03

From the results of measurements of CO gas levels in the burning of mosquito coils, an average gas measurement of 7.06 ppm was obtained and the CO sensor has a distance limit of measuring gas levels at a distance of 40 cm.

CH4 Sensor Measurement Results

Measurement of CH_4 gas, which used 25 ml of liquid chemicals in the form of methanol with solution concentrations of 25%, 50%, 75%, and 100% then the gas content of each concentration was measured for 10 minutes. Measurements of the limit reading of the CH_4 sensor were also carried out at a measurement distance of 10 cm - 60 cm. The results of this CH_4 gas measurement can be seen in Table 6 and Table 7.

Table 6. *CH_4 Sensor Measurement Results*

Minute	**CH_4 Concentration (ppm)**			
	25%	**50%**	**75%**	**100%**
1	0.42	1.50	2.86	4.38
2	0.31	1.73	2.42	4.10
3	0.10	5.78	1.61	5.02
4	0.14	2.17	2.05	6.18
5	0.18	1.38	2.63	4.69
6	0.24	2.52	3.12	5.60
7	0.14	1.30	3.72	3.66
8	0.14	1.39	3.12	4.71
9	0.17	1.86	2.42	3.97
10	0.19	1.50	2.22	6.12
	Average (ppm)			
	0.21	1.97	2.45	4.49

Table 7. *CH_4 Sensor Distance Limit Test*

Distance (cm)	**CH_4 Concentration (ppm)**
10	2.34
20	2.19
30	1.72
40	0.30
50	0.23
60	0.07

From the results of this measurement, it is known that the concentration of solutions of 25%, 50%, 75%, and 100% has an average gas content of 0.21 ppm, 1.97 ppm, 2.45 ppm, and 4.49 ppm. When compared with the threshold value for CH_4 levels, which is 1000 ppm, the value of this measurement is still below the threshold value and is still considered safe. CH_4 sensor measurement distance limit is at a distance of 60 cm with measurement results of 0.07 ppm.

NH3 Sensor Measurement Results

Measurement of NH_3 gas levels used 25 ml of liquid ammonia with variations in a solution concentration of 25%, 50%, 75%, and 100%. Measurements of the limit of the NH_3 sensor readings were also carried out at a measurement distance of 10 cm - 50 cm. The results can be seen in Table 8 and Table 9.

Table 8. *NH_3 Sensor Measurement Results*

Minute	NH_3 Concentration (ppm)			
	25%	50%	75%	100%
1	0.23	0.39	0.94	4.41
2	0.22	0.43	1.01	3.67
3	0.29	0.67	1.04	4.41
4	0.27	0.60	1.04	4.41
5	0.24	0.54	1.04	4.02
6	0.24	0.51	1.08	5.60
7	0.17	0.50	1.12	2.27
8	0.16	0.49	0.81	4.41
9	0.20	0.38	1.26	2.58
10	0.18	0.48	1.08	3.67
	Average (ppm)			
	0.22	0.50	1.04	3.95

Table 9. *NH_3 Sensor Distance Limit Test.*

Distance (cm)	NH_3 Concentration (ppm)
10	1.01
20	0.64
30	0.35
40	0.14
50	0.10

From the results of this measurement, the average value of the measurement is 0.22 ppm for a 25% solution concentration, 0.50 ppm for a 50% solution concentration, 1.04 ppm for a 75% solution concentration, and 3.95 ppm for a 100% solution concentration. When compared with the threshold value for NH3 levels, which is 25 ppm, the value of this measurement is still below the threshold value and is still considered safe [16]. The NH3 sensor has a measurement distance limit of more than 50 cm.

Buzzer Test Results

In the temperature and humidity sensors test, the measurement results are obtained as shown in Table 10. Based on the results of this test, it is known that the buzzer can sound when the sensor reading exceeds the set value.

Table 10. *Buzzer Test*

Parameters	Buzzer
Room Temperature > 30°C	On
Room Temperature ≤ 30°C	Off
Room Humidity > 60 %	On
Room Humidity ≤ 60 %	Off
CO, CO_2, NH_3, CH_4 Gas > 1 ppm	On
CO, CO_2, NH_3, CH_4 Gas ≤ 1 ppm	Off

Delay Time Test Results

Delay time testing is done by comparing the difference between the time of sending data and the time of receiving data. This test was carried out for 1 minute. The results of this test can be seen in Table 11. Based on these results, the average delay in sending sensor reading data from the Raspberry Pi to the UI Node-RED is 0 seconds or there is almost no delay in sending data to the UI.

Table 11. *Delay time test*

Time		Time Difference
Sending Data	Receiving Data	
18:13:03	18:13:03	0:00:00
18:13:10	18:13:11	0:00:01
18:13:15	18:13:15	0:00:00
18:13:21	18:13:21	0:00:00
18:13:27	18:13:27	0:00:00
18:13:31	18:13:31	0:00:00
18:13:37	18:13:37	0:00:00
18:13:40	18:13:40	0:00:00
18:13:48	18:13:48	0:00:00
18:13:51	18:13:51	0:00:00
18:13:59	18:13:59	0:00:00
Average		0:00:00

Conclusion

Based on the results described previously, the conclusions are that IoT-based CO, CO2, CH4, and NH3 gas detectors have been built and functioning properly. This instrument is capable of measuring CO, CO2, CH4, and NH3 gas levels, measuring room temperature and humidity, sending sensor reading data to be displayed on the LCD and UI Node-RED, and sounding a buzzer if the sensor reading value exceeds the specified limit values.

The measurement results from this instrument are the average measurement of CO and CO2 gas levels from the burning of mosquito coils are 7.06 ppm and 5.05 ppm. The average of CH4 gas at 25 ml of methanol with concentrations of 25%, 50%, 75%, and 100% is 0.21 ppm, 1.97 ppm, 2.45 ppm, and 4.49 ppm. The average measurement of NH3 gas in 25 ml of liquid ammonia with concentrations of 25%, 50%, 75%, and 100% is 0.22 ppm, 0.50 ppm, 1.04 ppm, and 3.95 ppm. The average laboratory temperature and humidity are 29.0°C and 70.7%, respectively. There is no delay in sending the sensor reading data from the Raspberry Pi to the UI Node-RED.

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