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Prototype Design of Automatic Switching Speed of Exhaust Fan For Air Quality Control Based On IoT

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***Abstract*—Bad indoor air quality is dangerous for humans body health because many people tend to do indoor activities so that it makes a house become a micro environment that related to air pollution risk. Therefore, this research has a goal to make an automatic air quality control system that can be online monitored where exhaust fan rotation speed is controlled by exhaust fan switching speed form a few dimmer that has a different power to decrease indoor air pollutant concentration instead. The system has been made, is using MG-811 as CO_2 concentration detector placed in the component box and Opto-interrupter sensor to measure exhaust fan airflow rate. The analysis results showed that MG-811 has error average is 0.93% while the accuracy is 99.07% and airflow rate has average error is 1.65% while the accuracy is 98.35%. The experiment result showed that the prototype able to respond the change of CO_2 concentration by switching the speed level of the exhaust fan but the monitoring system still has few a data loss because it is disconnected from the surrounding wifi.**

Keywords*—*switching speed system, exhaust fan, automatic, internet of things, air quality

I. Introduction

Bad indoor air qualities is dangerous for human body health. therefore one of the ways to make bad air qualities able to leave the room is by making a ventilation system that has a function to flow air from inside to the outside of the room. An exhaust fan is one of the tools from mechanical ventilation to prevent toxic concentration contamination [1]. but an exhaust fan that is sold in the market has no automatic speed control system according to CO_2 concentration variance.

With current technology, indoor air quality monitoring able to connect with the internet where IoT Technology can overcome data limit storage in an embedded systems. so that device no need to save data to the device memory because data is saved online[2]. Internet of things can be efficient if data computation and visualization can be done online or accessed through a cloud [3].

Previously there were studies related to air quality. namely, those proposed by Fadli Pradityo and Nico Surantha. The paper proposes the creation of a monitoring and controlling system for indoor air quality based on IoT and fuzzy logic using PM10, CO_2 sensors and exhaust fans as actuators. The system proposed in that journal has a fuzzy control that can adjust the exhaust fan working time interval automatically depending on the concentration of each pollutant so that the system does not control the speed of the exhaust fan [2]. Misbakhul Munir and Bayu Erfianto conducted research related to exhaust fan control. This study proposes a distributed fuzzy logic to control the exhaust fan speed based on the distribution of carbon monoxide which is read by the smoke detector sensor (4 sensors used), and several controllers. However, the system made aims to remove CO gas or carbon monoxide such as cigarette smoke or fire smoke using the MQ7 sensor [4]. Based on the problems above. In this case, an exhaust fan speed switch system will be made as an indoor air quality controller with an online monitoring system. The idea of this prototype is to find a new way to control the exhaust fan speed based on the concentration of CO_2 scattered in the room along with monitoring air quality control systems such as the concentration of CO_2 scattered in the room and the airflow rate exhaled by the exhaust fan. The sensor used is a CO_2 mg-811 sensor and an airflow rate sensor made using an opto-interrupter. of these gases individually in a polluted environment [5]. Therefore, in the tool that will be made the MG-811 sensor, because the MG-811 sensor is a sensor that is sensitive to CO_2 only and can be used under ambient conditions, can show variations in CO_2 concentration levels and can also operate effectively within a measuring range of 400 ppm – 2000 ppm [6].

The exhaust fan speed control that will be made is run by a switching system with the on/off control method, this is because the on/off control method is simpler and is often used in domestic control systems [7]. *On/off control is usually used in the control of process variables with slow changes* [8].

II. Method

Three setpoints are made, namely when the CO2 concentration is below 500 PPM then all relays are inactive, when between 500-600 PPM then relay 1 is active, when between 600-700 PPM relay 2 is active and when it is between 700 PPM then relay 3 is active. Dimmer 1 and dimmer 2 have different current outputs so that they will produce different exhaust fan rotation speeds. Relay 3 is a relay that directly

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connects the exhaust fan to the AC voltage source so that the exhaust fan will rotate at maximum speed. Block diagram of control system can be seen in figure 1.

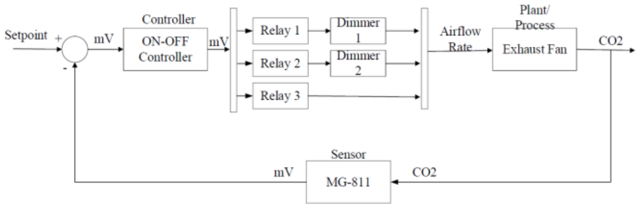


Figure 1 Control System Block Diagram

In its implementation, the prototype can be placed on the wall where the exhaust fan is connected to a stopcontact which is connected to the output of the prototype which can be seen in Figure 3, in the image there is a stopcontact A and a stopcontact B. Exhaust Fan is connected to the prototype output so that the exhaust fan is connected to the stopcontact A. Prototype is connected to the PLN source so that the prototype is connected to the stopcontact B. In Figure 2 is the placement of the components of the prototype. From the picture, the MG-811 sensor is used as a CO_2 detector which is placed in the component box, this is to make it easier for the sensor to detect the CO_2 concentration which is uneven in the air in the room where the component box is given an air suction fan whose blowing leads directly to the MG sensor - 811. In Figure 2 the airflow rate sensor is placed behind the exhaust fan. In the prototype there is an LED indicator of air quality with 4 colors, namely green, yellow, blue and red.

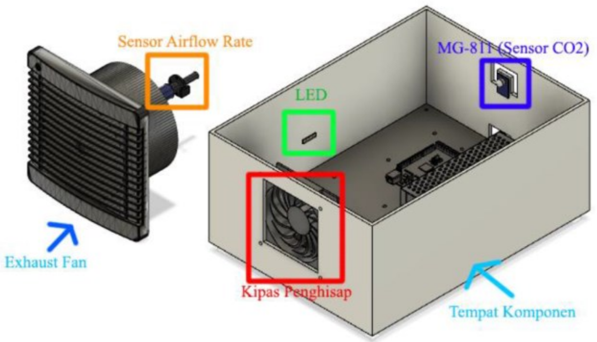


Figure 2 Component Placement

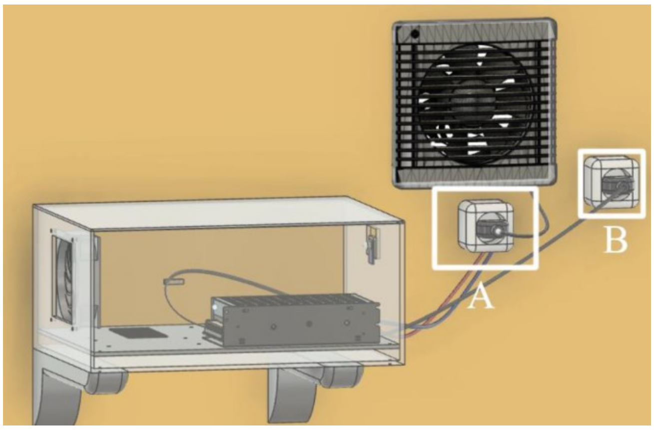


Figure 3 Example of Prorotype Installation

The prototype uses an Arduino Mega 2560 as a microcontroller, uses 2 sensors, namely the MG-811 CO2 detection sensor and an airflow rate sensor which is made using an opto-interruptor sensor. In order to ensure that the concentration of CO_2 is dispersed in the indoor air and also to monitor the performance of the exhaust fan, an online monitoring system is created. The block diagram of the prototype can be seen in Figure 4.

Figure 4 Prototype Block Diagram

According to Figure 5, the working principle of the hardware control system scheme is as follows:

a. First, Arduino Mega will read the PPM value through the MG-811 sensor, the Airflow rate through the MOC70T3 sensor and the fan speed level.
b. After that, Arduino Mega will use the NodeMCU ESP8266 as a station to connect to nearby wifi and the internet, then send sensor data and fan speed levels to the database.
c. After sending sensor data and fan speed levels to the database, Arduino Mega will use the MG-811 sensor data to adjust the exhaust fan speed by activating one of the pins connected to the relay so that the relay becomes normally open and the voltage from the power supply flows to the dimmer. Each dimmer has a different current so the exhaust fan speed depends on the active dimmer.
d. After the exhaust fan speed is determined, then Arduino Mega will send data on the exhaust fan speed level to the server and turn on the LED indicator based on the speed level.

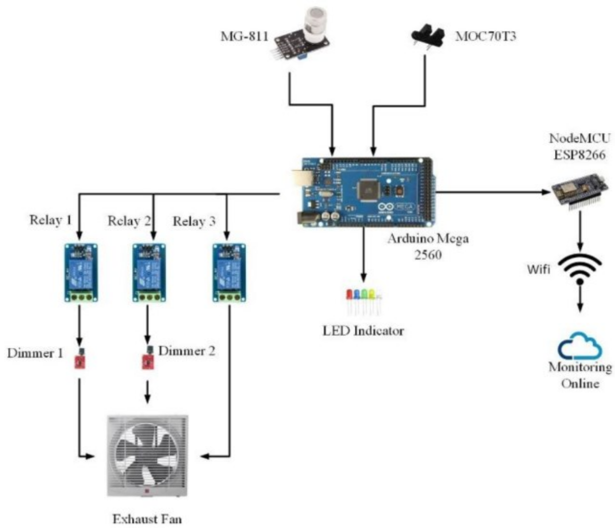


Figure 5 Detailed Hardware Schematic of Automatic Indoor Quality Control System

In the prototype is made, there is a monitoring system to monitor air quality and exhaust fan performance accroding to the airflow rate of the exhaust fan blowing.

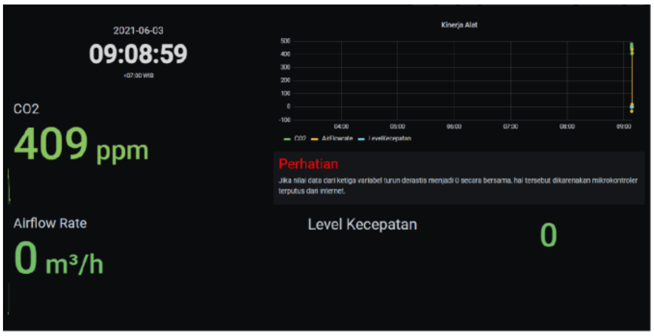


Figure 6 Monitoring

Figure 6 is a monitoring dashboard display from a prototype air quality control in the Grafana cloud. On the monitoring dashboard, there are indicators of speed level, CO_2 concentration and airflow rate. And there is a graph of the comparison of speed, CO_2 and air flowrate levels. On the dashboard there is also a table containing the variables stored in the database on google spreadsheet.

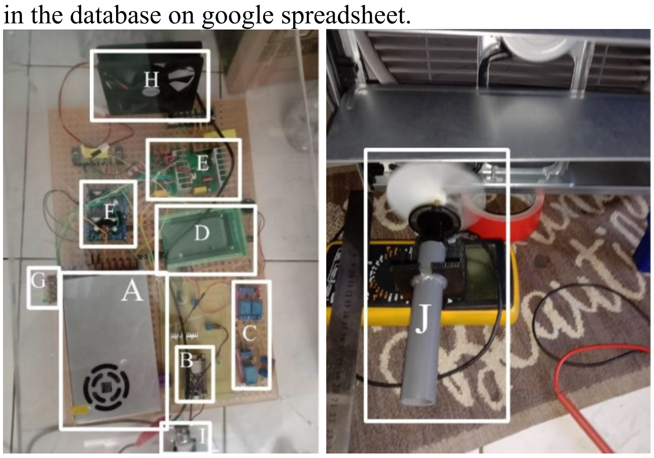


Figure 7 Prototype Component of Air Quality Control

Figure 7 is the result of the prototype design. In the picture the components have been integrated with each other according to the wiring diagram that has been made. The following is a description of the components in Figure 6:

A. Power Supply 24 V
B. NodeMCU ESP8266
C. Relay
D. Arduino Mega 2560
E. Dimmer
F. Buck Converter
G. LED
H. DC Fan
I. MG-811
J. Sensor Airflow rate

III. Results And Discussion

In the test results, several tests were carried out, namely testing the MG-811 sensor, testing the airflow rate sensor, testing the prototype and the results of the monitoring design.

A. MG-811 Test

The test was carried out by comparing the MG-811 CO_2 sensor with a standardized CO_2 measurement tool, the GC-2028 Lutron, with CO_2 test gas derived from dry ice sublimation. The data retrieval time interval is every 10 seconds. From the validation data that has been obtained, a linear regression equation is used so that the MG-811 sensor reading can approach the validator, the linear regression equation for the MG-811 is $\bar{y}_t$= -74.85773 + 0.57891396x. Figure 8 is a graph showing that the sensor readings are close to the validator readings.

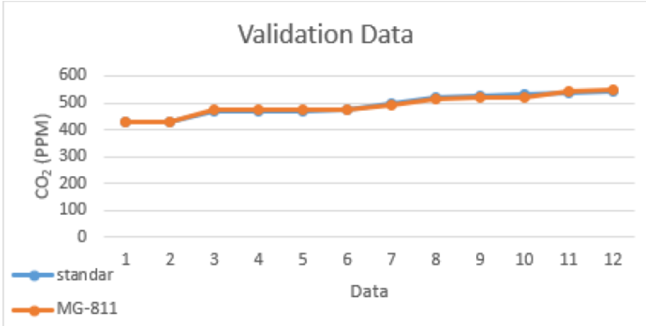


Figure 8 MG-811 Sensor Data Graph Testing After Validation

The static characteristics of the MG-811 sensor are as follows:

a. Average Error = -0.5 PPM
b. Percent Error = 0.93%
c. Accuration = 99.07%
d. Sensitivity = 1.21 mV/PPM
e. Standart Deviation/Repeatability = 34.33

There is the linearity graph on the MG-811 where the value of the CO_2 concentration read is inversely proportional to the output voltage on the MG-811 so that the greater the CO_2 concentration value, the smaller the output voltage on the MG-811.

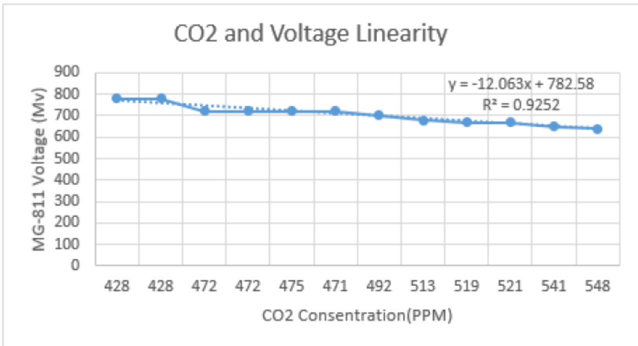


Figure 9 Linearity

From the test results above, it can be seen that the MG-811 sensor value is close to the validator value, namely the GC-2028 Lutron which can be seen in Figure 8 with an error percentage of 0.93% and an accuracy of 99.07% so that the sensor is suitable for use as a CO_2 detector but the sensor The MG-811 has a repeatability of 34.33, which means that it has poor repeatability of readings because the standard deviation value is more than 0, but because the accuracy value is 99.07%, the sensor is still suitable to be used as a CO_2 detector. The linearity graph in Figure 9 shows that the gradient of the line is negative, which means the linear line is slanted to the x-axis, which means that the output voltage of the MG-811 sensor is inversely proportional to the concentration of CO_2, where the greater the concentration of CO_2, the smaller the output voltage produced. In the linearity graph, it can be seen that R_2 = 0.93 or R_2 = 93% which means that the x-axis, namely "CO_2 concentration" affects the y-axis "MG-811 Voltage (mV)" by 93% while the other 7% is influenced by unknown variables.

B. Airflow Rate Sensor Test

The test is carried out by comparing the airflow rate sensor with the Benetech GM816 digital anemometer validator. The data retrieval time interval is every 10 seconds. From the validation data that has been obtained, a linear regression equation is used so that the airflow rate sensor reading can approach the validator, the linear regression equation for the airflow rate is $\bar{y}_t$= -0.207142857+0.01x. Figure 10 is a graph showing that the sensor readings are close to the validator readings.

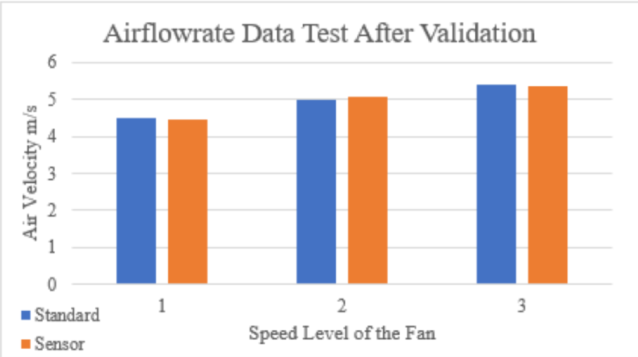


Figure 10 Airflow Rate Sensor Testing Data After Validation

However, because the data that has been validated is still in the form of a unit of speed m/s, where the need for the tool made is the airflow rate of the air released by the exhaust fan and each exhaust fan has a different wall opening, the formula is then used Q = (A.v).3600 to convert the Speed value to airflow rate where A is the wall opening of the exhaust fan of 34 cm x 34 cm = 0.1156 m2.

The static characteristics of the airflow rate sensor are as follows:

a. Average Error = 0 m/s
b. Percent Error = 1.65%
c. Accuration = 98,35%
d. Sensitivity = 0.32 Pulse/CMH
e. Standard Deviation / Repeatibility (m/s level 1)

Table 1 Data To Find the Standard Deviation of Airflow Rate

Speed Level	No	m/s	$x_i-\bar{x}$	$(x_i-\bar{x})^2$
1	1	4.48	0.01	0.0002
	2	4.48	0.01	0.0002
	3	4.48	0.01	0.0002
	4	4.33	-0.13	0.0173
	5	4.48	0.01	0.0002
	6	4.33	-0.13	0.0173
	7	4.48	0.01	0.0002
	8	4.48	0.01	0.0002
	9	4.62	0.16	0.0259
	10	4.48	0.01	0.0002
Total		44.60		0.0621
Average		4.46		

Standard Deviation/Repeatablity =0.0069

then the data is taken to get the hysteresis graph, range, span and linearity graph:

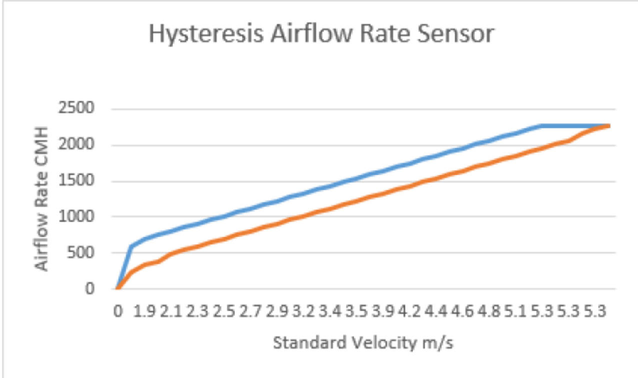


Figure 11 Hysteresis Sensor Airflow Rate

f. Range = 0 – 2266 CMH.
g. Span = 2266 CMH
h. Linearity

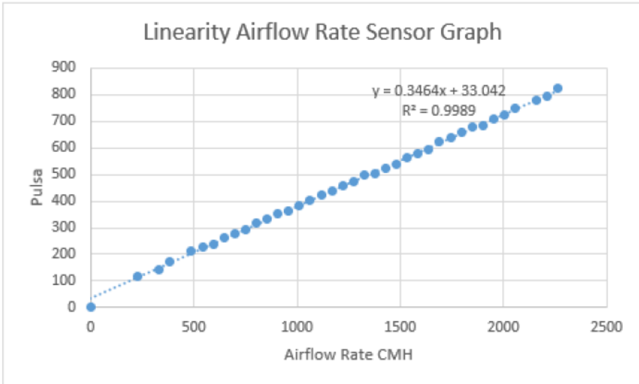


Figure 12 Airflow Rate Sensor Linearity

From the test results above, it can be seen that the airflow rate sensor value is close to the validator value, namely Benetech GM816 which can be seen in Figure 10 with an error percentage of 1.65% and an accuracy of 98.35% with a repeatability of 0.0069 so that the sensor is suitable for measuring blowing air from the exhaust fan. In the linearity graph in Figure 12 it can be seen that the gradient of the line is positive indicating that the pulse (output) of the airflow rate sensor is directly proportional to the airflow rate (input) where the greater the value of the airflow rate, the greater the pulse generated. In the linearity graph, it can also be seen that R_2 = 1 or R_2 = 100%, which means that the x-axis, namely the "airflow rate" affects the y-axis "Pulse" by 100%.

C. Prototype Test

The following is a prototype test of the exhaust fan speed switching system as an air quality controller by giving treatment to the prototype with CO_2 test gas and treatment without giving CO_2 test gas to the prototype. Here are the results of the prototype test. In the prototype , every speed level is generated from 3 different current variants. The current variant of each speed level is shown in table table 2 where the data is taken by measuring the prototype output.

Table 2 Current Output

Level 0	Level 1	Level 2	Level 3
0 mA	1.3–1.4 mA	1.8 mA	2 mA

At each speed level produces a different airflow rate. The airflow rate of the speed level is attached in table 3 where the data is taken by measuring the airflow rate of each speed level of the exhaust fan under conditions without the influence of changes in CO_2 concentration with the distance between the sensor and exhaust fan is 6 cm.

Table 3 Airflow Rate of Each Speed Level

Level 0	Level 1	Level 2	Level 3
0 CMH	436-541 CMH	1430-1691 CMH	1691-1796 CMH

The following is sample data from prototype testing carried out with 2 treatments, namely given CO_2 exhaust and not, where each treatment data collection was carried out each for 5 minutes with each data taken every 3 seconds so that the total data collection was carried out for 10 minutes.

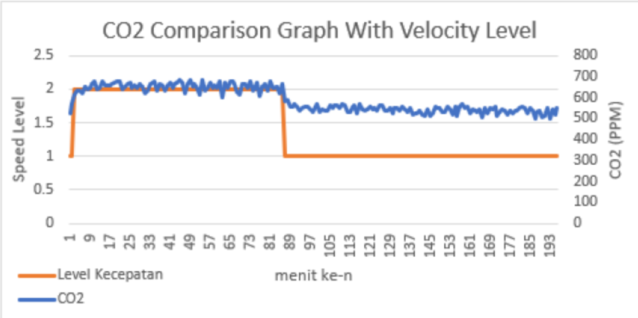


Figure 13 Graph of CO2 Comparison with Speed Levels (Sample)

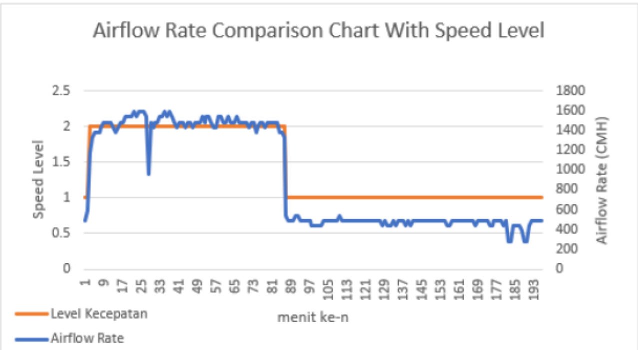


Figure 14 Graph of Comparison of Airflow Rate with Velocity Level (Sample)

From the control response, it can be seen that the response of the on-off control algorithm is in accordance with the designed control concept, namely when the CO2 concentration is between 600 PPM to 700 PPM, the speed level is 2 and when it is between 500 PPM to 600 PPM, the speed level is 1. This can be seen in the respone shown in Figure 13. From the respone shown in Figure 14, it can be seen that by switching the exhaust fan speed, we can control the airflow rate of the exhaust fan where when the speed level 2, the airflow rate is between 1400 - 1600 m^3/h and when the speed level 1, the airflow rate is between 400 - 600 m^3/h.

D. Result of Monitoring

In Figure 15, it can be seen that the green LED on the connectivity indicator has been on, indicating that the ESP8266 nodeMCU has been connected to the internet or connected to nearby wifi.

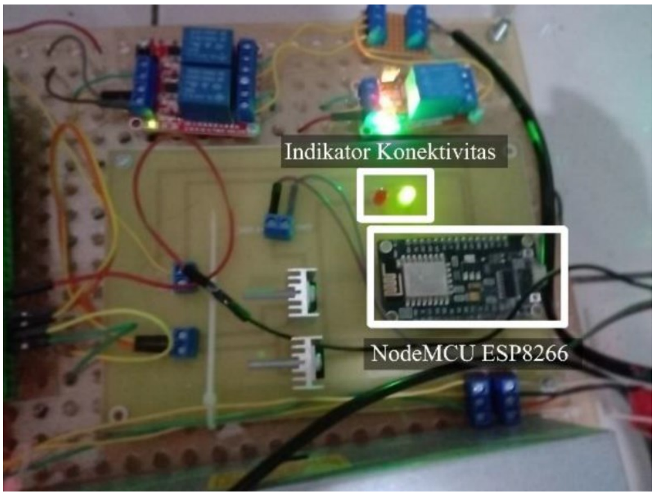
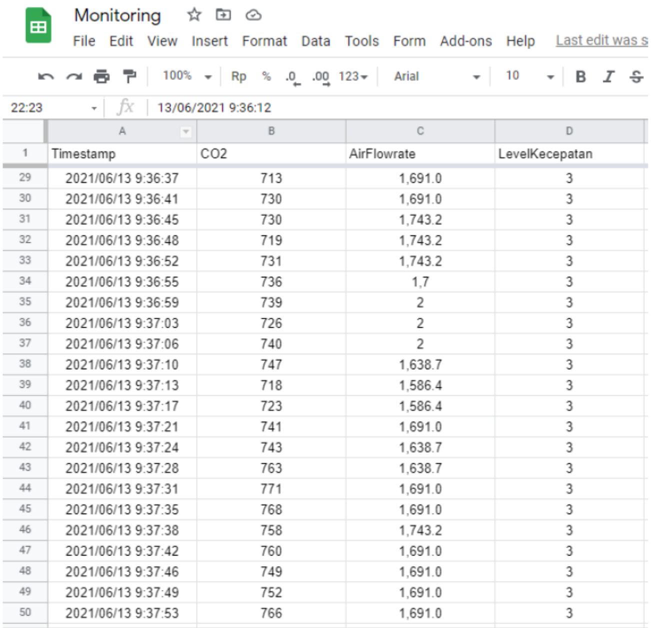


Figure 15 NodeMCU ESP8266 Wifi Connected

Figure 16 is the result of sending data to google spreadsheet. NodeMCU ESP8266 is able to send data to Google Sheets within 3 seconds when the internet is stable. However, in data transmission, packet loss occurs so that the data sent is 0.



	Timestamp	CO2	AirFlowrate	LevelKecepatan
29	2021/06/13 9:36:37	713	1,691.0	3
30	2021/06/13 9:36:41	730	1,691.0	3
31	2021/06/13 9:36:45	730	1,743.2	3
32	2021/06/13 9:36:48	719	1,743.2	3
33	2021/06/13 9:36:52	731	1,743.2	3
34	2021/06/13 9:36:55	736	1,7	3
35	2021/06/13 9:36:59	739	2	3
36	2021/06/13 9:37:03	726	2	3
37	2021/06/13 9:37:06	740	2	3
38	2021/06/13 9:37:10	747	1,638.7	3
39	2021/06/13 9:37:13	718	1,586.4	3
40	2021/06/13 9:37:17	723	1,586.4	3
41	2021/06/13 9:37:21	741	1,691.0	3
42	2021/06/13 9:37:24	743	1,638.7	3
43	2021/06/13 9:37:28	763	1,638.7	3
44	2021/06/13 9:37:31	771	1,691.0	3
45	2021/06/13 9:37:35	768	1,691.0	3
46	2021/06/13 9:37:38	758	1,743.2	3
47	2021/06/13 9:37:42	760	1,691.0	3
48	2021/06/13 9:37:46	749	1,691.0	3
49	2021/06/13 9:37:49	752	1,691.0	3
50	2021/06/13 9:37:53	766	1,691.0	3

Figure 16 Google Sheets Database

Figure 17 shows that grafana is able to display the data stored in the database. In grafana itself, the dashboard will update the data every 5 seconds while the data is sent to the database every 3 seconds so that the total data is updated every 8 seconds.

Figure 17 Monitoring On Grafana

The evidence for monitoring access to grafana via a laptop is shown in Figure 18.

Figure 18 Monitoring On Grafana Via Laptop

IV. Conclusion

The conclusions from the final project report with the title Design of a prototype automatic exhaust fan speed switching system as an IoT-based air quality controller are as follows:

a. The MG-811 sensor has been successfully validated with the static characteristics being the, error percentage is 0,93% and accuracy is 99,07%.
b. The airflow rate sensor has been successfully validated with the static characteristic being the percentage error is 1.65% and accuracy is 98,35%.
c. The prototype of the exhaust fan speed switching system has been successfully created as an air quality controller where the control system on the prototype has been able to respond the changes of CO2 concentration and switch the exhaust fan speed based on changes in the CO2 concentration.
d. The online or internet of things-based monitoring system has been successfully created where data is sent to the google spreadsheet database and then the data is displayed on Grafana with a data update delay is 8 seconds.

Acknowledgment

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References

[1] G. Wang and M. Liu, “Using multi-stack and variable-speed-drive systems to reduce laboratory exhaust fan energy,” *Int. J. Energy Res.*, vol. 29, no. 1, pp. 1–12, 2005, doi: 10.1002/er.1032.

[2] F. Pradityo and N. Surantha, “Indoor Air Quality Monitoring and Controlling System based on IoT and Fuzzy Logic,” *2019 7th Int. Conf. Inf. Commun. Technol.*, pp. 1–6, 2019.

[3] S. Kumar and A. Jasuja, “Air quality monitoring system based on IoT using Raspberry Pi,” *Proceeding - IEEE Int. Conf. Comput. Commun. Autom. ICCCA 2017*, vol. 2017-Janua, pp. 1341–1346, 2017, doi: 10.1109/CCAA.2017.8230005.

[4] M. Munir, “A Distributed Fuzzy Logic with Consensus for Exhaust Fan Controller,” 2020.

[5] V. Kalra and C. Baweja, “International Journal of Advanced Research in Influence of Temperature and Humidity on the Output Resistance Ratio of the MQ-135 Sensor,” no. November 2018, 2016.

[6] C. Shen and C. Shen, “An Investigation of a Low-cost CO2 Indoor Air Quality Monitor K133RP -Final Report An investigation of a low-cost CO 2 indoor air quality monitor,” no. March, 2015, doi: 10.13140/RG.2.1.3901.1364.

[7] Ogata, *Modern Control Engineering 5th*, vol. 39, no. 12. 2002.

[8] A. Ryniecki, “Basics of Process Control: the On-Off Control System,” *Przem. Spożywczy*, vol. 1, no. 11, pp. 28–31, 2015, doi: 10.15199/65.2015.11.6.