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Implementation of An Application-Based Motor Vehicle Exhaust Emission Level Detection System

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ABSTRACT

Currently, air conditions on earth are getting worse over time due to the impact of air pollution. One example of air pollution is motor vehicle exhaust emissions. Exhaust gas emissions are the result of combustion residue in motor vehicle engines that use fuel. Motor vehicle exhaust emissions contain carbon monoxide (CO), hydrocarbons (HC), carbon dioxide gas (CO2) which have a negative impact on the environment and living creatures. This research will create a motor vehicle exhaust emission detection device. In this design, an Arduino microcontroller was used and the manufacture of this tool used an MQ-7 gas sensor to detect carbon monoxide (CO) gas, an MQ-2 sensor to detect hydrocarbon gas (HC), and an MQ-135 to detect carbon dioxide (CO2) gas. The emission test results will be sent to the application, this data includes plate number, vehicle type, vehicle brand, vehicle year and emission test results. The results of the carbon monoxide (CO) gas sensor calibration test taken from 5 data showed an error of 5.51%. The results of the hydrocarbon (HC) gas sensor calibration test taken from 5 data showed an error of 4.23%. The results of the carbon dioxide (CO2) gas sensor calibration test taken from 5 data showed an error of 1.06%. In the implementation of the tool and application, the test results were obtained for 15 vehicles. Where the highest hydrocarbon (HC) gas content value was 412 ppm, the highest carbon monoxide (CO) gas content value was 1.48%, and the highest carbon dioxide (CO2) gas content value was 21.4%.

Keywords: *Arduino, Exhaust Gas Emissions, MySQL, MQ-2 Gas Sensor, MQ-7 Gas Sensor, MQ-135 Gas Sensor*

1. INTRODUCTION

Currently, the condition of the air on earth is getting worse over time due to the impact of air pollution. Air pollution changes the composition of the atmosphere, where one or more pollutants whose quantity and concentration can endanger the health of living things, damage property, reduce comfort in the air [1]. One example of air pollution is motor vehicle exhaust emissions. Exhaust emissions are the result of combustion residue in motor vehicle engines that use fuel [2]. These exhaust emissions are usually caused by imperfect combustion from the exhaust system and combustion in the vehicle engine. Exhaust emissions are one of the things that endanger human health and cause global climate change [3].

Motor vehicle exhaust emissions contain carbon dioxide (CO2), nitrogen oxide (NOx), carbon monoxide (CO), hydrocarbons (HC) which have a negative impact on the environment and living things. Therefore, along with the progress of the times, the latest production of motor vehicles is designed in such a way as to reduce the quantity of hazardous gases produced from their exhaust gases [4]. In setting national vehicle emission standards, Indonesia uses a decree based on the Minister of Environment and Forestry Number 8 of 2023 concerning the Implementation of Motor Vehicle Emission Quality Standards for Category M, Category N, Category O, and Category L.

Based on the above conditions, the author is interested in creating an Application-Based Motor Vehicle Exhaust Gas Detection System Implementation tool to determine the level of exhaust gas emissions in vehicles. Where this tool can detect levels of carbon monoxide (CO), hydrocarbons

(HC), and carbon dioxide (CO2) which can provide results simultaneously and are connected to the application to view vehicle exhaust gas emission test data.

2. LITERATURE REVIEW

2.1 Exhaust Gas Emission Quality Standards

Motor Vehicle Exhaust Gas Emission Quality Standards are the maximum limits of pollutants or substances that may be released directly from the exhaust pipes of motor vehicles. Good vehicle exhaust gas levels must follow the standard regulations set by the relevant agencies. Through the Minister of Environment and Forestry, the Minister of Environment and Forestry has issued Regulation of the Minister of Environment and Forestry Number 8 of 2023 concerning the Implementation of Motor Vehicle Emission Quality Standards for Category M, Category N, Category O, and Category L [5].

Table 1. Emission Quality Standards

Category	**Production year**	**Parameter**			**Test Method**
		Carbon monoxide (CO)	Hydrocarbons (HC)	Carbon dioxide (CO2)	
Powered by a spark-ignition combustion engine (petrol)					
4 Wheels	<2007	4%	1000ppm	12-15%	Idle condition
	2007-2018	1%	150ppm		
	>2018	0,5%	100ppm		
2 Wheels	<2010	5,5%	2200ppm	12-15%	Idle condition
	2010-2016	4%	1800ppm		
	>2016	3%	1000ppm		

3. METHODS

3.1 Block Diagram

The design of this system consists of block diagrams, hardware planning and software design. In designing hardware and software, at this stage each component will be assembled into a connected unit.

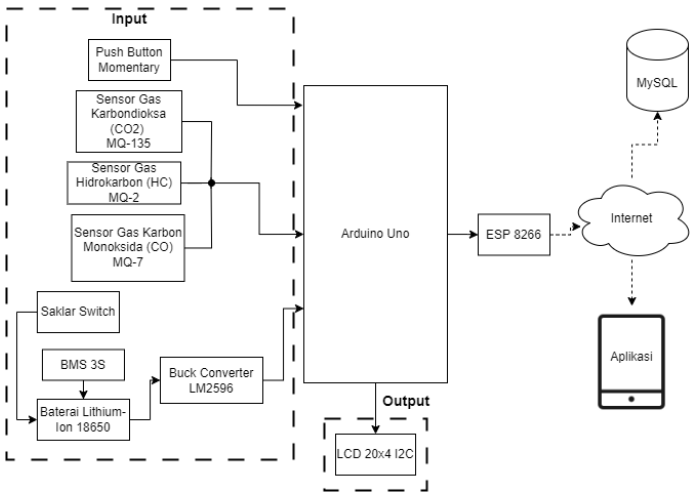

Figure 1. System Block Diagram

For the input of the system includes, Arduino uno as a data processing microcontroller, ESP8266 as a connecting module to the internet, MQ-2 gas sensor to measure hydrocarbon gas levels (HC), MQ-7 gas sensor to measure carbon monoxide gas levels (CO), MQ-135 gas sensor to measure carbon dioxide gas levels (CO2), switch function to turn the device on/off, Momentary Push Button function to send test results to the database, 18650 Lithium Ion Battery function as a device voltage source, Buck Converter LM2596 to reduce voltage from Arduino Uno, BMS 3s function as a battery charger module and to protect the battery from excessive current, MySQL to store vehicle emission test data results. For the output of the system includes a 20x4 LCD function to display exhaust gas levels. Arduino uno and ESP8266 collection, data sending via the internet, data storage in the database, and accessed by users via the application.

3.2 System Flowchart

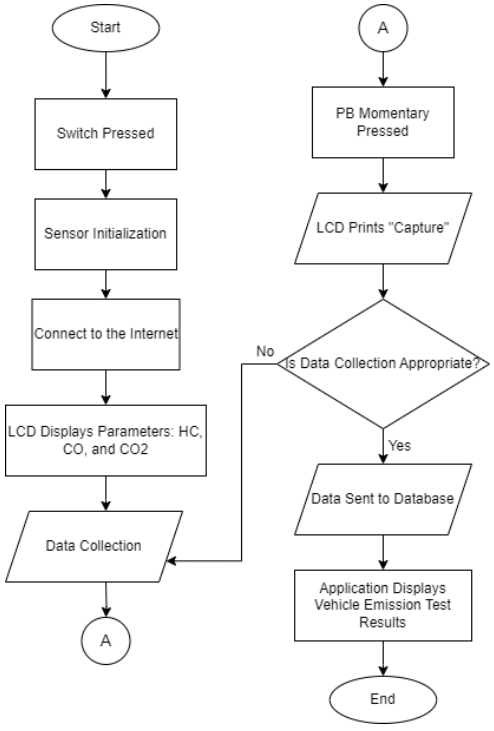

Figure 2. Diagram Flowchart System

The tool flowchart in Figure 2 shows the process flow from initialization to sending data to the sensor to the application. The process begins by turning on the device, after the device is turned on, sensor initialization is continued by connecting the device to the internet. The LCD will display the sensor value with HC, CO, and CO2 parameters. Then, take data on the vehicle to be tested. Press the push button to send the vehicle emission test results to the database. The LCD will print "Capture" indicating that the data has been stored in the database. If the capture is deemed appropriate, proceed to the next step. If the data capture is not appropriate, then retest. After printing "Capture", the application will display the vehicle emission test results.

3.3 System Flowchart

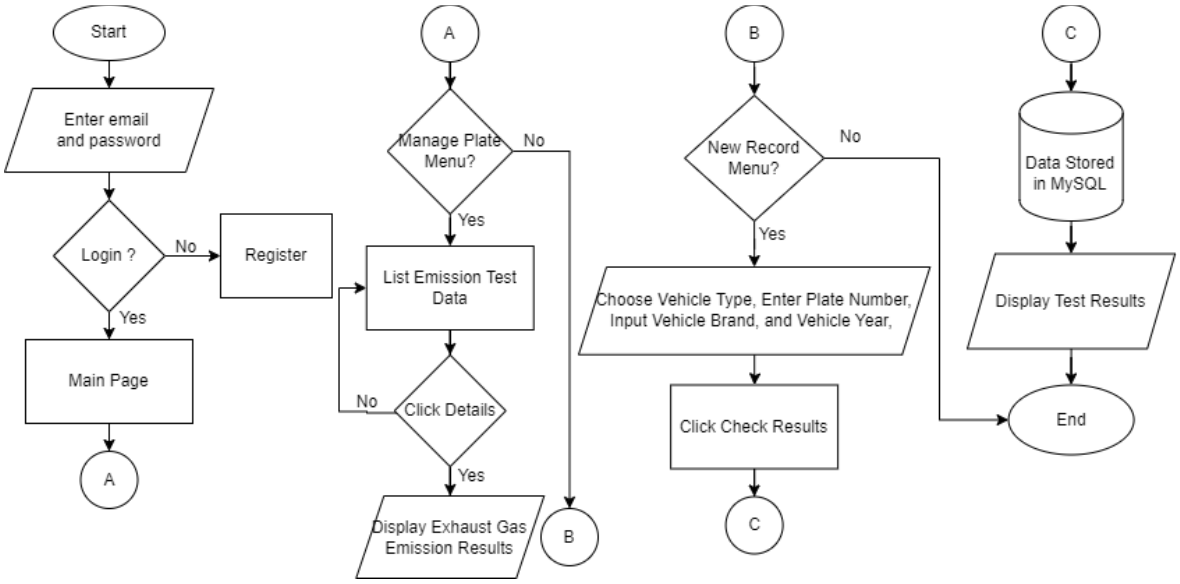

Figure 3. Diagram Application Flowchart

The application created functions as an output from monitoring the tested vehicle. Users open the application and log in using email and password. If they do not have an account, they must register first. However, if the user already has an account, they can log in directly and continue to the main menu page. After successfully logging in, there are 2 menus on the main page, if the user wants to see the vehicle record history, they are directed to the manage plate menu. The manage plate menu will display data on the results of vehicles that have been tested and click details to see the results of the exhaust gas levels in the vehicle. If the user wants to add a vehicle to be tested for emissions, they are directed to the new record menu by selecting the type of vehicle, entering the plate number, vehicle brand, and vehicle year. After testing the vehicle, the data is stored in the MySQL database, then the results of the vehicle emission test will be displayed.

3.4 Diagram Wiring

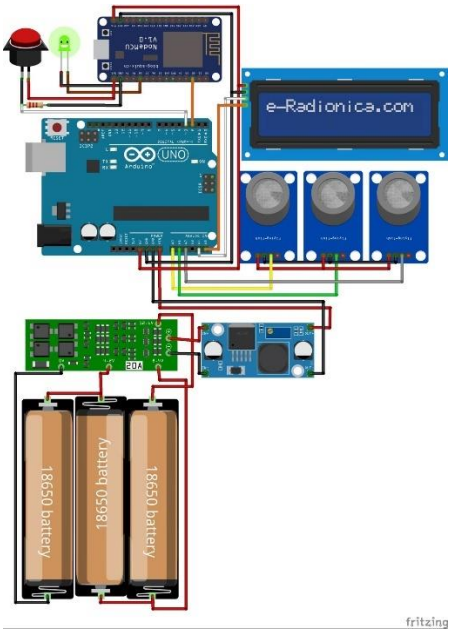

Figure 4. Diagram Wiring

In Figure 4, the wiring of each sensor with other devices is shown. In this system, the sensor functions as input, while the microcontroller acts as a controller that processes data from the sensor before sending it to the Application.

4. RESULTS AND DISCUSSION

This chapter will cover the comprehensive outcomes of the planned activities, encompassing both the software and hardware design. It will include the results of sensor testing that will be utilized in the project.

Figure 5. Mechanical Engineering Lab, State Polytechnic of Malang

4.1 Tool Making Results

Figure 6. Tool design results

Figure 7. Sensor location results

The devices that have been made in this research consist of 2 tool boxes, namely a microcontroller box and a sensor box.

4.2 Application Creation Results

The following are the results of the application design that has been created:

Figure 8. Menu Login View

Figure 8 is a login display, where the user will be asked to enter a username and password. If you do not have an account, you need to register by pressing "Don't have an account?"

Figure 9. Menu Register View

Figure 9 is the registration page display, where the user will be asked to enter a username, email and password to create a new account.

Figure 10. Main Menu View

Figure 10 is the main menu display after logging into the application, where there are 2 menus, namely "New Record" and "Manage Plate".

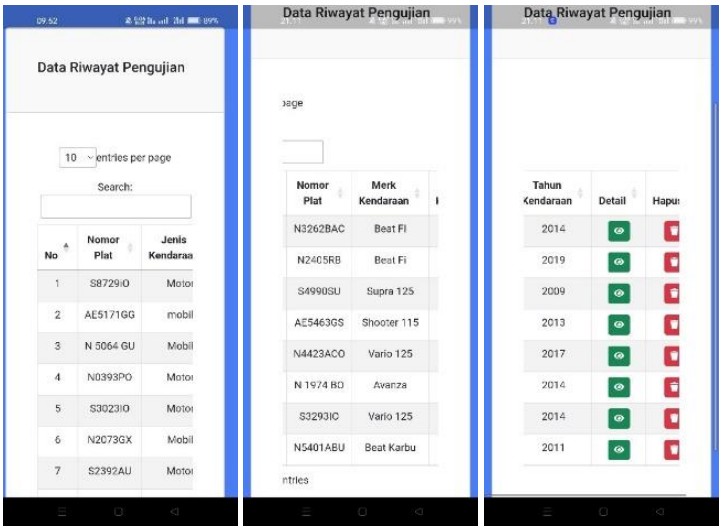

Figure 11. Manage Plat Menu Display

Figure 11 is a display of the license plate management menu which will display the history of vehicles that have been tested including the license plate number, vehicle type, vehicle brand and vehicle year.

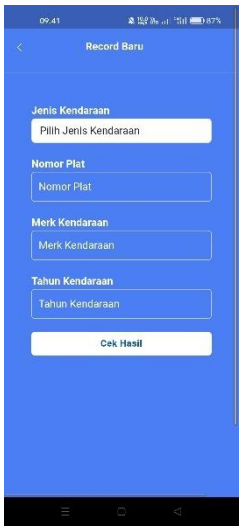

Figure 12. New Record Menu View

Figure 12 is a new record menu display. In this menu, the user will select the type of vehicle, then enter the license plate number, vehicle brand, and vehicle year. This data will then be stored in the MySQL database.

Figure 13. Test Result Display

Figure 13 the conclusion for vehicle status is in 2 conditions, namely "Good" and "Bad". The parameters for these 2 conditions are HC, CO, and CO2. The threshold values for motorbikes and cars are different. For motorbikes, the threshold value for the HC parameter is 1800 ppm, the threshold value for the CO parameter is 4% and the threshold value for the CO2 parameter is 12-15%. For cars, the threshold value for the HC parameter is 150 ppm, the threshold value for the CO parameter is 1%, the threshold value for the CO2 parameter is 12-15%. If one of the parameters is below the threshold, it will display the conclusion "Good", and if one of the parameters exceeds the threshold, it will display the conclusion "Bad".

4.3 Sensor Calibration

The calibration process of the tool aims to adjust the sensor output value to the actual value. The method used in this study is to compare the output value with a valid tool, namely using the HG-520 gas analyzer.

Figure 14. Gas Analyzer HG-520

1. CO Gas Sensor Testing

Table 2 CO Gas Sensor Testing

No.	CO (%)		Error (%)
	Gas Analyzer	LCD	
1	4,32	3,84	11,11
2	4,34	3,97	8,53
3	4,36	4,29	1,61
4	4,41	4,29	2,72
5	4,45	4,37	1,80
Average error (%)			5,15

2. HC Gas Sensor Testing

Table 3. HC Gas Sensor Testing

No.	HC (ppm)		Error (%)
	Gas Analyzer	LCD	
1	1.463	1.380	5,67
2	1.470	1.395	5,10
3	1.480	1.420	4,05
4	1.487	1.429	3,90
5	1.496	1.460	2,41
Average error (%)			4,23

3. CO2 Gas Sensor Testing

No.	CO (%)		Error (%)
	Gas Analyzer	LCD	
1	7,3	7,09	2,88
2	7,3	7,23	0,96
3	7,3	7,28	0,27
4	7,4	7,33	0,95
5	7,4	7,38	0,27
Average error (%)			1,06

Based on table 2 (CO gas sensor testing) shows an average error of 5.15%, table 3 (HC gas sensor testing) shows an average error of 4.23%, and table 4 (CO2 gas sensor testing) shows an average error of 1.06%.

4.4 Overal System Testing and Analysis

Before the sample is tested for each data tested, the vehicle needs to be accelerated with maximum torque for ± 1 minute to stabilize the vehicle's exhaust gas. After the vehicle engine is stable, measurements of HC, CO, and CO2 pollutants in the vehicle's exhaust gas can be carried out.

Figure 15. Overall system test results

The results of vehicle emission pollutant testing can be seen as follows.

Table 4. Overall Test Results

No	Vehicle	Vehicle Year	Emission Testing Equipment			Conclusion
			HC (ppm)	CO (%)	CO2 (%)	
1	Vario 125	2014	137	1,04	13,33	Good
2	Vario 125	2017	174	0,44	12,69	Good
3	Beat Karbu	2011	412	1,47	11,75	Good
4	Supra 125	2009	276	0,66	1,5	Good
5	Shooter 115	2013	78	0,88	21,4	Bad
6	Avanza	2014	207	0,26	3,48	Bad
7	Beat FI	2019	52	0,25	1,6	Good
8	Beat FI	2014	126	0,44	12,34	Good
9	Avanza	2014	118	0,20	2,98	Good
10	Beat Karbu	2013	250	1,39	12,50	Good
11	Shogun 125	2011	176	1,1	13,34	Good
12	Mio GT	2013	213	0,90	12,44	Good
13	Scoopy FI	2018	45	0,37	2,45	Good
15	Mio J	2012	227	1,48	13,50	Good

Table 4 is the result of vehicle testing with HC, CO, CO2 levels operating around the city of Malang. Where in the tested vehicles, the highest Hydrocarbon (HC) gas level value is 412 ppm, the highest carbon monoxide (CO) gas level value is 1.48%, the highest carbon dioxide (CO2) gas level value is 21.4%. From the results of the test table 4.4, the hydrocarbon (HC) gas level value and the carbon monoxide (CO) gas level value are still below the set threshold, while for the carbon dioxide (CO2) gas level value, some are still below the ideal value and some are above the ideal value. If the CO2 level is too low but CO and HC emissions are normal, it could indicate a leak in the exhaust pipe.

CONCLUSION

Based on the creation and testing of the system carried out in the previous chapter, it can be concluded for this study that:

1. The results of the design and implementation of the Application-Based Motor Vehicle Exhaust Gas Detection System were successfully designed. Where this system uses an MQ-2 gas sensor to measure hydrocarbon gas (HC) levels, an MQ-7 gas sensor to measure carbon monoxide (CO) gas levels, and an MQ-135 gas sensor to measure carbon dioxide (CO2) gas levels.
2. The sensors used can be calibrated with the results of the carbon monoxide (CO) gas sensor calibration test taken from 5 data showing an error of 5.15%. The results of the hydrocarbon (HC) gas sensor calibration test taken from 5 data showing an error of 4.23%. The results of the carbon dioxide (CO2) gas sensor calibration test taken from 5 data showing an error of 1.06%.
3. In the implementation of the tools and applications, the results of the test were obtained for 15 vehicles. Where the highest hydrocarbon gas (HC) content value is 412 ppm, the highest carbon monoxide (CO) content value is 1.48%, and the highest carbon dioxide (CO2) content value is 21.4%.

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