Portable machine with android application display for measuring CO and HC of vehicle exhaust gas

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Abstract. Two main pollutant components produced by vehicle exhaust gas are hydrocarbon (HC) and monoxide carbon (CO). At the car service center, these two gasses are measured using a commercial instrument called as automotive emission analyzer (AEA). However, this instrument is not practicable for personal daily used. Problems that would be discussed in this publication involving how to design and build a simple and portable instrument for measuring HC and CO gasses. The objective of the published research is to measure HC and CO gasses and then displayed them in the Android-based smartphone. In the designing and building step, MQ-2 and MQ-7 sensors were used to detect HC and CO gasses respectively. The produced data of MQ-2 and MQ-7 sensors were processed and calculated using Arduino and then the results were sent to be displayed in the Android-based smartphone. The result showed that MQ-2, MQ-7 with Arduino was successfully implemented for building portable HC and CO measuring instruments. When compared to commercial AEA, the measurement resulted from the developed instrument has an average error of 2 ppm for HC and 0.0075% for CO.

1. Introduction

Motorized vehicles including motorcycles, cars, trucks, and buses produce exhaust emissions that contain substances that would pollute the air. Of all components of vehicular emission, the most dominant pollutant are carbon monoxide (CO) and Hydrocarbon (HC). Carbon monoxide (CO) gas is the product of imperfect combustion. The nature of CO gas is colorless, odorless and tasteless and if inhaled by humans at certain levels will be able to affect human health ranging from dizziness and nausea to the danger of death in a short time [1].

Electronics systems offer high potential to be applied for environmental monitoring including gas. By using electronic systems, the presence of the gas, especially the hazardous gasses could be detected and then the alert system could be set in place for people to avoid polluted areas [1]. There is some examples of research published in this area such as for water quality monitoring [2],[3],[4], LPG gas leakage monitoring [5],[6], air quality monitoring regarding for traveling [7].

The two main components of electronics-based environment monitoring systems are sensors and microprocessors including a microcontroller. The microcontroller is a signal processing device which is small in size but very reliable for use in a variety of applications and implementations such as in the development of a wheeled robot for detecting the presence of flammable gas [8] and for air quality monitoring [9].
The electronics environment monitoring systems could be implemented either for outdoor such as in [8] and [10] or for indoor environments such as [11]. Besides being able to display the computation results locally, for example, using liquid crystal display (LCD), microcontroller able to send the data to the remote device. The advantage of sending data to the remote device is the measurement results could be monitored in some distance away from the location where the measuring device is placed. There are numerous technology reported were used for monitoring environment remotely such as in CO gas detection with the measured data was displayed to the PC through serial cable [12]. Another data communication was using short message services (SMS) was implemented for sending the data of CO gas measurement [1]. Data communication using SMS was also used for environment monitoring [13], [14]. The microcontroller was also reported to send the measurement of environmental data through general packet radio services (GPRS) [15]. Further application of wireless communication data in computer monitoring was using radiofrequency with frequency 433 MHz [10]. For a wide area to be monitored, wireless sensor networks (WSN) that use short-range wireless data communication were applied for environment monitoring [16].

Because of the bad influence on health, CO gas levels in the environment, especially on motor or automobile vehicle exhaust emissions need to be monitored. Research on the design and development of electronics systems for monitoring air pollution has received attention from researchers such as [17],[18],[19] and other similar works. The weakness of all the systems that have been published is that the measuring instrument is only devoted to measuring CO gas only. Hydrocarbon monitoring was rarely reported by researchers previously. In this article, we will discuss the design and construction of a system to measure two parameters, namely CO and HC gases at the same time. Also, the usage of smartphones for displaying the measurement results will be presented.

In this published work, the Arduino microcontroller is used as the main processing instrument. The objective of this published research is to measure CO and HC gas levels in motor vehicle exhaust emissions electronically based on the microprocessor system and display them on smartphone applications based on the Android operating system.

2. Method

2.1. System Architecture

In the research that has been done, to measure HC gas levels MQ-2 gas sensor is needed while measuring the CO gas MQ-7 gas sensor is needed. An MQ-7 gas sensor is able to detect the presence of CO gas with levels between 20-2000 parts per million (ppm). MQ-2 and MQ-7 gas sensors will detect HC and CO gas levels which are non-electric quantities and then convert them into electrical signals which are then sent to the Arduino microcontroller circuit for processing. In this publication, Arduino microcontroller was used because it has widely used including for environment monitoring such as in greenhouse [20] or in a wireless sensor network architecture for detecting gas leakage in a wide area [21]. The overall system architecture can be seen in Figure 1.

![Figure 1. Block diagram representing the architecture of the systems](image)

The Arduino microcontroller will process the detected signal from the sensor and then display it into the viewer and on a mobile device that is a smartphone with the Android operating system wirelessly using Bluetooth communication.
2.2. Hardware design

The overall system architecture in Figure 1 was then realized into a hardware circuit whose schematic diagram can be seen in Figure 2. Both MQ-2 and MQ-7 sensors require a power supply from a 5V DC resource used to power the sensor and also as a reference voltage for the gas sensor output. The magnitude of the sensor output voltage is linear with the amount of HC and CO gas levels. The Arduino microcontroller-based system then processed the sensor signal using a program planted in it which then sends the processed data to an Android smartphone via a Bluetooth communication module to display the results.

![Schematic diagram of hardware connection](image)

Figure 2. Schematic diagram of hardware connection

2.3. Software design

The program flowchart could be seen in Figure 3.

![Flowchart of the program](image)

Figure 3. Flowchart of the program
The program of Arduino microcontroller was developed using the Arduino IDE. The program is started with the initialization of the sensor and Arduino microcontroller. Then, the Arduino microcontroller recognized which sensor was chosen active and received the data and calculated the concentration of related variables either for CO or HC gas. After that, the calculated data was sent to the smartphone through the Bluetooth communication module.

2.4. Construction design
In order to protect the hardware circuit from damage and then also for mobility, the sensor, Arduino microcontroller and its supporting device and circuits were placed into tube containers and box respectively. Also, a small pipe is needed for catching gas emissions so that enough to be censored by the two sensors. The whole construction design of the monitoring systems is depicted in Figure 4. Part A is the exhaust of the vehicle that functions as a drain for burning vehicles. Part B is the connecting pipe between the muffler and the tube where the sensor is placed. Part C is a sensor that has the function to detect the gas that is channeled through the connecting pipe. Part D is a round tube that serves as a place to put the sensor. Part E is the cable that functions as a sensor input to the Arduino microcontroller. Part F is the Arduino Uno microcontroller. Arduino Uno microcontroller uses Atmega 328 microcontroller which has 14 digital input and output pins. Part G is a Bluetooth module that functions as a receiver and sender of signals from Arduino and Android smartphones. The H section is the box or place used to put the Arduino and Bluetooth module.

3. Results and discussion

3.1. The resulted systems
The actually resulted in monitoring systems can be seen in Figure 5. Microprocessor-based systems are put in black plastic boxes to protect them from impact or water droplets. In the developed system, there is a small pipe used to capture the air to be measured of CO and HC gas content. The prison pipe is then connected to a can where there is a place for the MQ-2 and MQ-7 sensor circuits. The detection results by the MQ-2 and MQ-7 sensors were then sent to the microprocessor system which is placed in a black box by using cable media. The computational results of CO and HC gas levels by the microprocessor are then sent to the Android operating system-based smartphone to be displayed using a specially created application. The total weight of the systems is 800 grams so it is very easy to carry (portable) for use by people.
3.2. System and smartphone connection test
In this test, the device is turned on and the measurement results are sent via Bluetooth media to be displayed with the application on a smartphone. The distance between the devices made with a smartphone is tried to vary starting from less than one meter then the distance plus one meter. The test results show that the smartphone can still receive measurement results properly and display the measurement results in a maximum application at a distance of seven meters. At a distance of more than seven meters, the connection is less stable.

3.3. Measurement test
Testing the performance of the tool that has been made is done experimentally by trying to measure the exhaust emissions on the vehicle directly. To find out its validity, the results of measurements using developed systems were compared with that of commercial gauges commercially available on the market / used in car repair shops namely the automotive emission analyzer (AEA). Testing was done by measuring the exhaust emissions of cars that are widely used by the people in collaboration with national official workshops in the city of Surakarta where the car has always checked the level of exhaust emissions periodically at the same time during service or maintenance. The test scenario can be seen in Figure 6.

![Figure 6](image)

At the time of testing, a small pipe was inserted into the exhaust pipe of the car so that the exhaust gas emissions entered the pipe so that there was enough gas to be detected by the sensor. The measurement results displayed on the smartphone application were then recorded. Then the exhaust emissions of the same car were then measured using a commercial AEA device. The two measurement results were then compared. Measurements were made in two conditions, namely: (1) when the engine speed is kept at a minimum close to zero revolution per minute (rpm) ie the gas pedal is not pressed/stepped on, (2) when the engine is rotating at 2000 rpm.

3.4. Testing results at zero rpm
The first test was done by turning on the car engine for five minutes at zero rpm then measuring the HC and CO gas. The results of measuring HC and CO gas levels using a device made compared to using AEA are shown in Table 1.
Table 1. Test results of HC and CO measurement at zero rpm: comparison between the developed systems and AEA: Δ is the difference between measurement results of developed systems and AEA

| Vehicle | Manufacturing year | Type of fuel | Measurement Result at zero rpm |
|---------|--------------------|--------------|--------------------------------|
|         |                    |              | The concentration of HC (ppm) | The concentration of CO (%) |
|         |                    |              | Developed Systems | AEA | Δ | Developed Systems | AEA | Δ |
| Car 1   | 2011               | Premium      | 12               | 10  | 2 | 0.02              | 0.02 | 0  |
| Car 2   | 2013               | Premium      | 17               | 17  | 0 | 0.02              | 0.01 | 0.01 |
| Car 3   | 2016               | Premium      | 3                | 2   | 1 | 0.01              | 0     | 0.01 |
| Car 4   | 2014               | Premium      | 7                | 6   | 1 | 0.01              | 0     | 0.01 |
| Average of Δ |                  |              | 1                |         | 0.0075          | 5 |

3.5. Testing at 2000 rpm

The second test was carried out by turning on the car engine for five minutes at zero rpm and then measuring its CO and HC gas levels. The measurement results using the developed instrument and its comparison with the measurement results using AEA can be seen in Table 2.

Table 2. Test results of HC and CO measurement at 2000 rpm: comparison between the developed systems and AEA: Δ is the difference between measurement results of developed systems and AEA

| Vehicle | Manufacturing year | Type of fuel | Measurement Result at 2000 rpm |
|---------|--------------------|--------------|--------------------------------|
|         |                    |              | The concentration of HC (ppm) | The concentration of CO (%) |
|         |                    |              | Developed Systems | AEA | Δ | Developed Systems | AEA | Δ |
| Car 1   | 2011               | Premium      | 27               | 26  | 1 | 0.05              | 0.03 | 0.02 |
| Car 2   | 2013               | Premium      | 29               | 28  | 1 | 0.03              | 0.02 | 0.01 |
| Car 3   | 2016               | Premium      | 11               | 9   | 2 | 0.01              | 0.01 | 0  |
| Car 4   | 2014               | Premium      | 21               | 17  | 4 | 0.01              | 0.01 | 0  |
| Average of Δ |                  |              | 2                |         | 0.0070      | 5 |

Based on the measurement results shown in Table 1 and Table 2 it can be noted that the results of measuring HC gas levels using a device that has a maximum difference (Δ) of 2 ppm while for the measurement of CO gas was 0.0075%. These results indicate that the developed systems able to measure HC and CO levels at low concentrations and the results are acceptable because it has a very small difference when compared to commercial AEA devices which are widely used in car repair shops. When compared with existing AEA commercial, the developed systems has advantages in terms of its mobility, which is small and light so that it is easily moved to various locations (portable) and also uses an Android application-based viewer so that it is easy to store the data and for distribution (no need to record or print the measurement results).
4. Conclusion
From the results of the design and development process, it can be concluded that MQ-2 and MQ-7 sensors have been successfully implemented to make portable devices to detect and measure the presence of HC and CO pollutant gases produced by vehicle exhaust emissions. Arduino microcontroller systems were successfully used for processing signals from MQ-2 and MQ-7 sensors and transmit data to smartphones wirelessly using Bluetooth media at a maximum distance of seven meters. The results of measurement tests show that the developed systems successfully measure HC and CO levels with an average difference of a maximum of 2 ppm for HC gas and 0.0075% for CO gas when compared with the results of measurements with commercial AEA equipment that is widely used by car repair shops. The results of this publication can be used for further research, for example in making databases and backend application programs that are connected to the payment system.

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