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Design Monitoring of Dust Density Levels in Air Filters of Air Conditioning for Enhance Room Air Quality

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ABSTRACT

Clean air quality is very important in maintaining human health. Increasing air pollution is increasingly worrying. The danger is the potential for injury, such as impaired lung function or even systemic poisoning. From this problem, a device was designed that was able to measure dust density in air filters of Air Conditioning (AC). This research is able to monitor dust density continuously. From the test results, the condition of air filter was obtained at the first dust density of 66 mg/m^3 (clean), the second 93–203 mg/m^3 (normal) and the third 251–413 mg/m^3 (unclean), then the alarm buzzer was ON. The dust density test was 238.7 mg/m^3 and the wind speed was 1.6 m/s with a voltage of 1.99 volts. It is hoped that this research would be useful in monitoring the dust density level in AC air filters, so that it could enhance room air quality.

Keyword: Alarm Buzzer, Air Conditioning Air Filter, Air Quality, Dust Density

1. Introduction

Currently, the issue of air pollution is becoming increasingly concerning [1], [2]. Air pollution can originate from a range of activities, such as industrial operations, transportation, offices, and residences [1], [3]–[5]. These diverse activities are responsible for the greatest amount of air pollution discharged into the atmosphere [2], [6], [7]. Air pollution can also arise from natural phenomena such as forest fires, volcanic eruptions, and the release of ancient harmful gases [1], [3], [6]. Air pollution reduces air quality, resulting in negative effects on human health [2], [5], [8], [9].

Dust is an unavoidable air contaminant in our daily lives. In specific circumstances, dust poses a hazard that can result in severe respiratory impairment, such as deadly lung dysfunction, or even lead to systemic poisoning [10], [11]. To address this issue, implementing effective air filtration systems within the house might serve as a viable alternative to rejuvenate one's physical well-being after a long day of outdoor activity [5], [8], [12], [13].

This research proposes a device designed to measure dust density levels in Air Conditioning (AC) air filters using the dust sensor GP2Y1010AUF [1], [3], [6]. This research is able to monitor dust density levels continuously, so that it can improve room air quality conditions and control air circulation systems.

2. Material and Methods

Optical Dust Sensor GP2Y1010AU0F

The Optical Dust Sensor GP2Y1010AU0F is a dust detector that uses infrared technology. This sensor is highly efficient in detecting minuscule particles, such as dust or cigarette smoke, and is frequently employed in air purification systems. This sensor operates by detecting the presence of dust or other particles and subsequently reflecting the light back to the receiver. The light is reflected by the particles on the entire surface and subsequently transformed into electrical voltage by the photodiode. Amplification of the voltage is necessary in order to detect and interpret the variations. The sensor produces an analog voltage that is directly proportional to the density of the observed dust. It has a sensitivity of 0.5 volts per 0.1 milligrams per cubic meter [1], [3], [5], [6].

Figure 1. Optical Dust Sensor [1], [3], [6]

Arduino Uno R3

Arduino is a single-board microcontroller that is open-source and derived from the Wiring Platform. It is specifically designed to simplify the use of electronics in many fields. The Arduino hardware utilizes an Atmel AVR processor, while the Arduino software is programmed using the C programming language. The memory of the Arduino can be described as follows: The device has a flash memory capacity of 32 kilobytes, a static random-access memory (SRAM) capacity of 2 kilobytes, and an electrically erasable programmable read-only memory (EEPROM) capacity of 1 kilobyte. The Arduino board's clock utilizes an XTAL with a frequency of 16 MHz. The Arduino Uno operates with an input voltage of approximately 5 volts. The Arduino Uno can be powered on by establishing a connection using USB. The Arduino Uno is equipped with 28 pins that are commonly utilized. The input/output (I/O) system comprises 14 individual channels, numbered 0 to 13. Among these channels, six are capable of generating pulse-width modulation (PWM) output. Specifically, these channels are 3, 5, 6, 9, 10, and 11. The Arduino Uno has 14 digital pins, each of which may function at a maximum voltage of 5 volts and can deliver or receive a maximum current of 40 mA. Analog input is comprised of six terminals, specifically labeled as A0 through A5. The pin leg serves as the input for voltage to the Arduino Uno when utilizing an external power source, such as an adapter, instead of USB [5], [6], [9], [10], [12], [14].

Liquid Crystal Display (LCD)

An LCD (Liquid Crystal Display) is a display medium that utilizes liquid crystals as its primary means of visual representation. Liquid crystal displays (LCDs) have found applications in diverse domains, including electronic devices like televisions, calculators, and computer screens. The post utilizes a dot matrix LCD with a character count of 2 x 16. The LCD is a display specifically designed to show the tool's operational status. The LCD interface utilizes a parallel bus, which facilitates efficient and rapid data transfer between the LCD and other devices. The ASCII code, represented by 8 bits, is transmitted to the LCD either in 4-bit or 8-bit chunks. In the case of using 4-bit mode, two nibbles of data are transmitted to form a complete 8-bit value. This is achieved by sending a 4-bit Most Significant Bit (MSB), followed by a 4-bit Least Significant Bit (LSB), with an EN clock pulse for each nibble. The EN control line is utilized to indicate to the LCD that the microcontroller is transmitting data to the LCD. In order to transmit data to the LCD, the program needs to set the EN line to a high state (represented by "1") and subsequently set the RS and R/W control lines. Alternatively, data can be sent directly to the data bus line [5], [6], [9], [10], [12], [14].

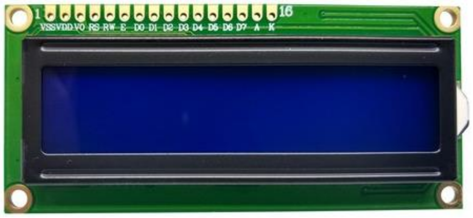

Figure 2. Liquid Crystal Display 16x2

Buzzer

An electric buzzer is an electronic device capable of transforming electrical signals into audible vibrations. The buz zer, an auditory apparatus, is commonly used in anti-theft systems, watch alarms, doorbells, truck backup alerts, and other devices that serve as hazard warnings. The most commonly encountered and utilized type of buzzer is the piezoelectric buzzer. The piezoelectric buzzer possesses several advantages, including cost-effectiveness, significantly lower weight, and ease of integration with other electronic circuits. This buzzer, classified as a member of the transducer family, is frequently referred to as a beeper. Unlike speakers, which require a dedicated amplifier to generate sound at a level audible to humans, this is a distinct and contrasting phenomenon. Piezo buzzers are effective for generating frequencies ranging from 1–5 kHz to 100 kHz, making them suitable for ultrasonic applications. The typical operational voltage range for a piezoelectric buzzer is generally between 3 and 12 volts [12], [15].

Figure 3. Buzzer

Flowchart of Dust on the room-conditioning Air filter

The goal of this study was to measure the amount of dust present on an air conditioner's air filter using an optical dust sensor. Dust monitoring is conducted when the sensor detects a concentration exceeding 249 mg/m3. Upon detection of dust levels, the buzzer will be triggered, and the parameter values for the dust level will be shown on the LCD. This technology is really beneficial for users when it comes to conducting air conditioning repairs. Figure 4 displays the tool system flowchart.

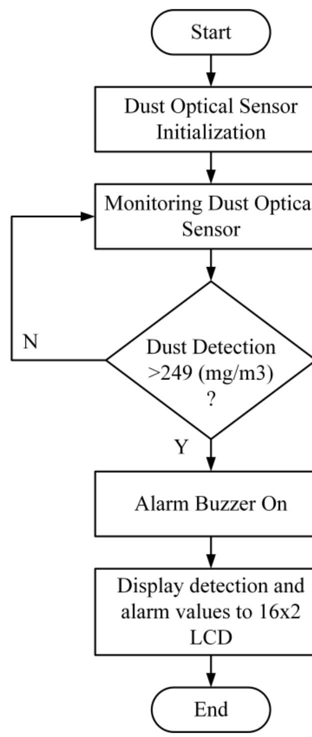

Figure 4. Flowchart Of Dust On The Room-Conditioning Air Filter

The following Pseudocode of Dust on the room-conditioning Air filter, as described in algorithm 1:

Table 1. Algorithm 1

Algorithm 1: Create Dust on the room-

conditioning Air filter system
1. Input optical dust sensor
2. Monitoring dust optical sensor
3. If Dust detection >249 (mg/m^3)
4. Then alarm buzzer on
5. Else monitoring dust optical sensor
6. Display detection and alarm values tp 16x2 LCD
7. End

Design of block diagrams

This study utilizes a GP2Y1010AUF sensor to measure the dust concentration in the air filter of the air conditioning system. The sensor readings are then transmitted to a display, which indicates the percentage of dust present in the air filter. This information enables residents to perform regular maintenance on the air conditioning system. The block diagram above illustrates that an input signal is required for processing and subsequent display via the output. The gp2y1010au0f sensor is utilized as an input in the design of this instrument to generate an analog signal, which is subsequently converted into a digital signal through processing. The gp2y1010au0f sensor is interfaced with an Arduino Uno R3 microcontroller, which subsequently analyzes the input from the dust sensor and activates the buzzer accordingly. The achieved results consist of monitoring the dust level value on the air conditioning filter and issuing a buzzer alarm to tell the user. This information allows the user to make the necessary modifications based on the findings. Figure 5 displays the block diagram image.

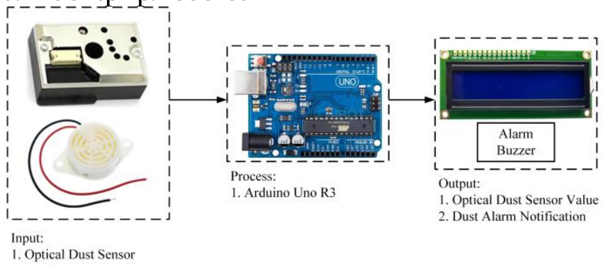

Figure 5. Design of Block Diagrams

3. Results and Discussions

This study involves conducting tests on a prototype of an air filter dust detection system in air conditioning units to determine its effectiveness and functionality. Experiments were conducted to measure dust levels, wind speed, voltage of the prototype, condition of the filter, and activation of the prototype's buzzer alerts.

Testing of Dust Density Detection

A test was conducted using the GP2Y1010AUF dust sensor to measure the amount of dust present on the air conditioning air filter. The sensor will detect whether the dust concentration exceeds 249 mg/m3. Subsequently, activate the buzzer alarm to transmit an alert to the air conditioning system's recipient. Table 1 displays the dust test data for the air filter.

Table 2. Testing of Dust Density on Air Filters

Test	Dust Density (mg/m3)	Status		
		Fan AC	Sensor	Buzzer
1	0-249	ON	ON	OFF
2	>249	ON	ON	ON

Table 1 demonstrates that the examination revealed the sensor's ability to detect dust on the air conditioning air filter. We measured the dust density value (mg/m3) and found that it ranged from 0 to 249 (mg/m3). This number triggers the air conditioning fan's activation, allowing the airflow in the room to circulate and preventing any disruption to the air filter.

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Moreover, in the event that a value over 249 (mg/m3) is detected, the air conditioning's buzzer alarm will be triggered. Consequently, it will lead to complications in the dissemination of the air conditioning fan across the space. When a high density of dust is detected, the user has the option to perform maintenance on the air conditioning's air filter.

Testing dust density against wind speed in air conditioning

The goal of this study was to evaluate the relationship between dust density and wind speed in air conditioning systems by implementing 10 trials. The collected findings consist of measurements of dust density (expressed in mg/m3), wind speed (measured in m/s), the status of the filter, and a buzzer that triggers the alert. Table 2 displays the data used to examine the relationship between wind speed and dust density.

Table 3. Testing Dust Density Against Wind Speed In Air Conditioning

Test	Dust Density (mg/m3)	Wind Speed (m/s)	Filter Condition	Alarm Buzzer
1	66	2.0	clean	Off
2	93	1.8	normal	Off
3	134	1.7	normal	Off
4	165	1.7	normal	Off
5	203	1.6	normal	Off
6	251	1.5	unclean	On
7	284	1.5	unclean	On
8	380	1.4	unclean	On
9	403	1.4	unclean	On
10	413	1.4	unclean	On
Avg	**238.7**	**1.6**		

According to Table 2, the comparison of dust density against wind speed yielded an average value of 238.7 mg/m3 for dust density and 1.6 m/s for wind speed. The test results presented in Table 2 indicate that the dust density value is 66 mg/m3 when the air filter is clean, ranging from 93 to 203 mg/m3 in a normal condition and from 251 to 413 mg/m3 in a filthy filter state. The buzzer alarm is activated when the dust concentration exceeds 249 mg/m3, alerting users to perform air conditioning maintenance. Figure 6 displays the test graph findings.

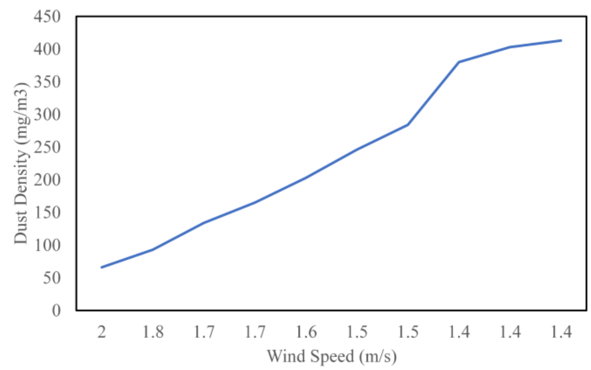

Figure 6. Graph Of Dust Density Testing Against Air Conditioning Wind Speed

Figure 6 demonstrates a direct relationship between the dust density achieved in the dust test on the air conditioning air filter and the decrease in wind speed. For experiment 1, the wind speed was measured at 2 m/s, which led to a dust concentration of 66 mg/m3.

Testing dust density against voltage values in air conditioning

The purpose of this test is to compare the density of dust in the air filter with the voltage value generated by the optical dust sensor. The experiment was conducted 10 times to assess the state of the air filter under test, determining whether it was clean, normal, or unclean. Additionally, the system was programmed to emit a buzzer alarm to alert the user, enabling them to do necessary repairs on the air conditioning unit. Table 3 displays the test table below.

Table 1. Testing Dust Density against Sensor Voltage Values in Air Conditioning

Test	Dust Density (mg/m3)	Voltage Value (V)	Filter Condition	Alarm Buzzer
1	66	1	clean	Off
2	93	1.1	normal	Off
3	134	1.4	normal	Off
4	165	1.6	normal	Off
5	203	1.8	normal	Off
6	251	2.1	unclean	On
7	284	2.2	unclean	On
8	380	2.8	unclean	On
9	403	2.9	unclean	On
10	413	3	unclean	On
Avg	**238.7**	**1.99**		

According to Table 3, the dust density test results for voltage values indicate an average of 238.7 mg/m3 and 1.99 volts. In this experiment, when the dust density increases, the corresponding measurement of sensor voltage will also increase. As the air conditioning air filter accumulates more dirt, a buzzer will be triggered to alert the user to perform maintenance on the air conditioning air filter. The effects of the dust density test graph on the voltage value in the air conditioning may be observed in graph 7.

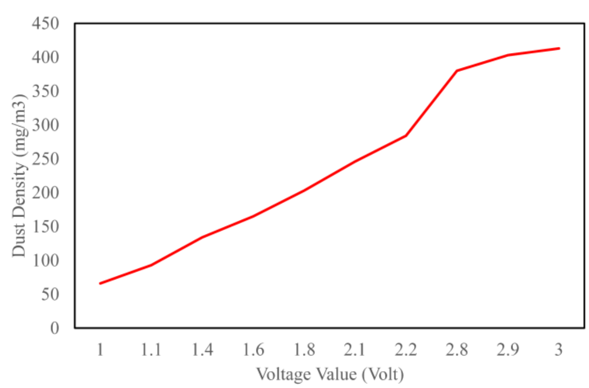

Figure 7. Graph of Dust Density Testing against the Voltage Value on the Air Filter of Air Conditioning

Figure 7 demonstrates a positive correlation between the dust density detected on the air filter and the resulting voltage value. As the dust density increases, it becomes denser, and the voltage value also increases. In this case, the maximum dust density detected was 413 mg/m^3, which corresponded to a voltage reading of 3 volts.

4. Conclusion

Based on the test results on the air conditioning air filter, the dust monitoring system produced an average dust density value of 238.7 mg/m^3. The air's velocity is 1.6 m/s, and the electric potential difference is 1.99 volts. During the examination of dust density in relation to wind speed, it was seen that the dust density level was 66 mg/m^3. This indicated a clean air filter condition. Under normal circumstances, the dust density ranges from 93 to 203 mg/m^3, while in the presence of a dirty filter, it can reach levels between 251 and 413 mg/m^3. Moreover, during the examination of the relationship between dust density and voltage, it was seen that as the dust density increased, the voltage value also increased. Specifically, a dust density of 413 mg/m3 corresponded to a voltage value of 3 volts. As the dust density value increases, the air filter becomes dirtier. Consequently, the system will emit a buzzer alarm warning when the dust density exceeds 249 mg/m^3. The detected dust density value is determined by the position of the sensor. It is recommended to install the sensor in a region with the highest dust potential.

Acknowledgement

This research was supported by the Department of Electrical Engineering and the Faculty of Engineering, Universitas Muhammadiyah Jakarta.

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