Development of intelligent monitoring purifier for indoor PM 2.5

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Abstract. The particulate matter 2.5 (PM2.5) refers to tiny particles or droplets in the air that are two and one half microns or less in width. PM2.5 is an air pollutant that is a concern for people's health when levels in air are high. The intelligent monitoring purifier was developed to detect indoor PM2.5 concentration before and after purification and the monitoring data could be displayed on the LCD screen, displaying different color patterns according to the concentrations. Through the Bluetooth transport module, real-time values could also display on the mobile phone and voice broadcast PM2.5 concentration level in the air. When PM2.5 concentration is higher than the setting threshold, the convection fan rotation and the speed can be remote controlled with mobile phone through the Bluetooth transport. Therefore, the efficiency and scope of the purification could be enhanced and further better air quality could be achieved.

1. Introduction

PM 2.5 in the air reduces visibility and causes the air to appear hazy when its levels are elevated. PM 2.5 pollution has raised serious concerns for public health. Currently, the outdoor PM2.5 monitoring technology has been developed more mature, and outdoor individual protection could be achieved by facial masks. In the daily mobile phone weather forecast we can observe the monitoring value of PM2.5 in the air. Indoor air purification usually relies on expensive and energy-intensive air-filtering devices and a wide range of purification possibilities and improves of the air situation need long-term plan to achieve as well [1-3]. PM2.5 pollution is particularly harmful since it can penetrate human bronchi and lungs owing to the small particle size. There have been serious PM pollution problems in developing countries, such as China. Students or office workers often stay indoors every day for more than 13 hours, the indoor air treatment/purification would not only improve the air quality in the living environment, but also solve the issues caused by PM2.5 disease incidence.

However, the price of indoor PM2.5 air purifier currently sold in the market is still high, and their functions cannot fully meet the customer requirements and need to be enhanced. For the market dominated by students and office workers, low-cost high efficiency PM2.5 air purifiers are demanded and it needs to be ensured that the function should be as complete as possible to avoid duplication consumption. This investigation was combined with the level of consumption and living conditions of students to develop a small simple PM2.5 monitoring purifier, which integrates the functions of monitoring, air purification, voice broadcast, Bluetooth data transportation, and air convection. The objective is to improve the air quality in student dormitory and ensure the comfort of college students living environment.

2. Indoor PM2.5 data monitoring and determination of air quality

Based on Arduino single chip, equipped with dust sensor (GP2Y1010AU0F SHARP) including conversion the parameters generated by the relevant devices, PM2.5 concentration monitoring is achieved. According to the national PM2.5 concentration segment and the corresponding air quality index, the concentration level grading is categorized through the design procedure and it is convenient to view the monitoring value of the PM2.5 concentration from the intelligent monitoring purifier for indoor PM2.5.

The PM2.5 detection principle is schematically described in Figure 1. The sensor center hole allows the sufficient free air flow. The directional launched LED light is using as source for detection of dust content in the air, which is determined via the light refraction after the light penetrates though the dust. The 24-hour mean value of PM10 in the air was obtained with the aid of the dust detection system.

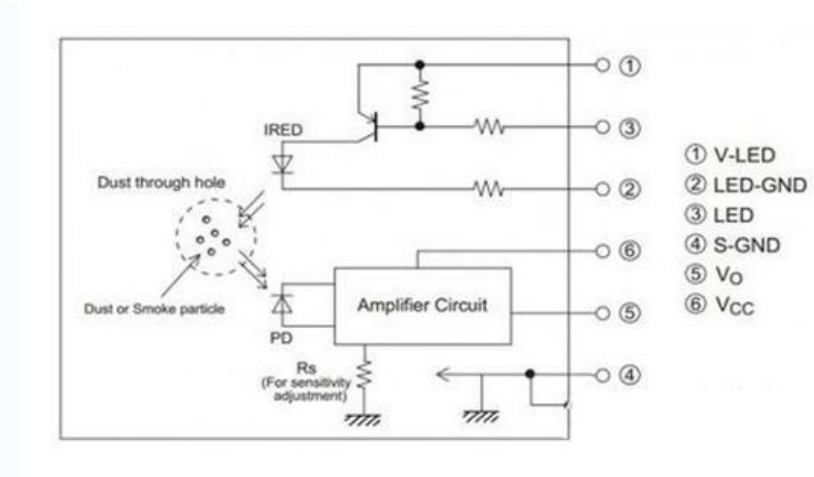

Figure 1. The diagram of the PM2.5 detection principle for the dust sensor (GP2Y1010AU0F SHARP).

The value corresponding to the dust sensor voltage is converted into dust density while the PM10 dust density into the PM2.5 dust density, the real-time data output to the monitoring device. The air quality level [4] is translated according to the 24-hour average of PM2.5 as shown in Table 1.

Table 1. The index of indoor air quality, category and color codes of air quality index

Index of Air Quality Level (IAQL)	PM2.5 24-hour Mean (μg/m^3)	Index of Air Quality (IAQ)	Level of IAQ	Category and Color Codes of Air Quality Index	
0	0	0~50	1st class	Excellent	Green
50	35				
100	75	50~100	2nd class	Good	Yellow
150	115	101~150	3rd class	Light Polluted	Orange
200	150	151~200	4th class	Medium Polluted	Red
300	250	201~300	5th class	Heavy Polluted	Purple
400	350	>300	6th class	Server Polluted	Dark Red
500	500				

In our investigation, Sharp dust sensor is used due to its cheaper price and easy use. Therefore, the entire product cost of the air purifier for indoor PM2.5 can be rational and acceptable easily by customers. Meanwhile, the program rewrite through the conveniently accessed process of parameter setting/resetting greatly not only enhance the writing ability of software design, but also improve the reliability of the molding products.

The software modules included Chinese characters are implemented to complete the programming of the liquid crystal display; the continuous improvement can be completed in the subsequent debugging and continuous testing. Ultimately, a complete dust sensor is applied to monitor the value and achieve the PM2.5 numerical conversion. Meanwhile, a display pattern is obtained based on the level of PM2.5 in the indoor air, the liquid crystal display can be based on PM2.5 numerical segment shows different expressions. The matrix diagram of the liquid crystal display principle is shown in Figure 2.

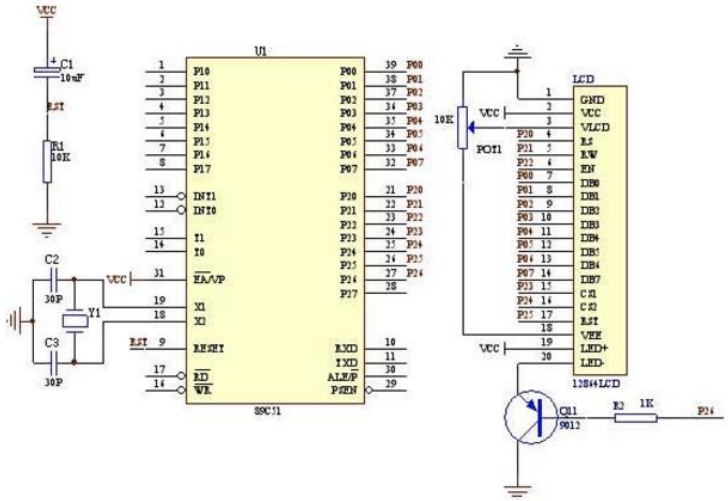

Figure 2. The matrix diagram of the liquid crystal display principle

3. Voice broadcast of PM2.5 concentration level

SYN6288 TTS serial speech integration module is used to support a variety of text code formats including GB2312, GBK, BIG5 and UNICODE. Therefore, the device can generate any Chinese text and support English alphabet text also. With intelligent text analysis and processing algorithms of those modules, the voice broadcast component can correctly identify the value, number, time and date and commonly used weights and measures units. It supports a variety of text control tags to enhance the correct rate of text processing. It also supports sleep function mode, in the sleep state the device can switch to another operation to reduce power consumption. The device supports a variety of ways to query the working state of chip and supports 16 volume adjust. The volume of the playback text and the volume of the background music can be controlled separately. The word speed of playback text can be adjusted by sending the control mark with 6 speed adjustment. The module pin structure and integrated connection of the microcontroller is show in Figure 3.

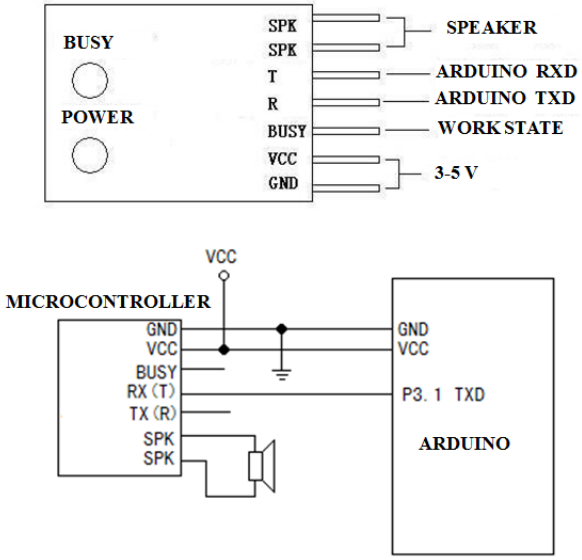

Figure 3. The matrix diagram of the liquid crystal display principle

Through SYN6288TTS serial speech integration module, the dust sensor output data can be successfully converted to voice and thus the real-time PM2.5 monitoring is achieved with the intelligent output. The main difficulty encountered in this work is time jump of PM2.5 monitoring data and the evolution value is not a fix number. Before and after the broadcast, the value of the PM2.5 concentration may change, sometime vary greatly, most likely even not in a same air quality level. Therefore, the broadcast method was adjusted from the instantaneous voice broadcast value to delayed broadcast value in order to avoid the time jump value caused inaccuracy and the air quality level is added. According to the value of air quality improvement or a slight reduction and additional the level broadcast, the owner has a general grasp of the indoor air quality. The final output is that the voice broadcast is at appropriate speed and easy to listen with the well-designed 16-level volume and 6-voice speed adjustment.

4. Indoor air purification for PM2.5

Multiple function-layer filters followed after the turbine fan is designed to guarantee the best indoor air purification as shown in Figure 4. The first layer of the purifier, non-woven air filter cotton, captures larger particles in the air, such as dust and hair; The second layer of activated carbon acts as the adsorbate for odor and harmful gases; The third layer of HEPA filter can capture the PM as small as 0.3 microns (PM = 0.3).

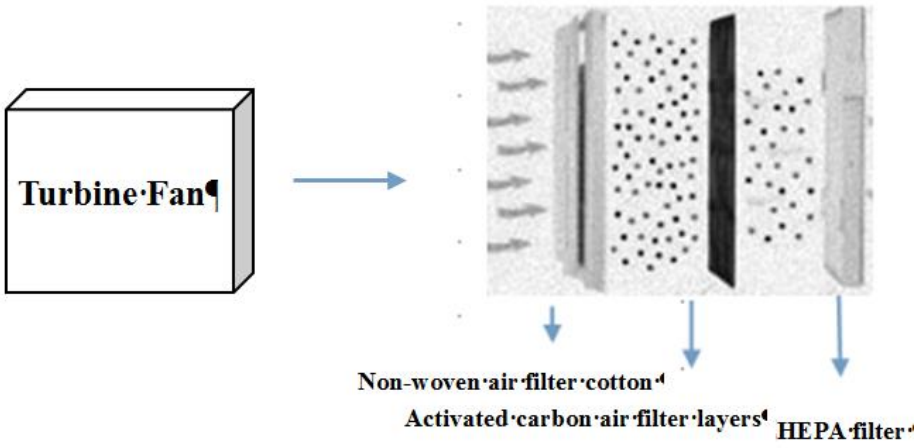

Figure 4. The schematic diagram of the multiple function-layer filters of the air purifier.

Turbine fans provide the sufficient air flow through the air purifier. With higher turbine fan speed, air flow volume increases and thus the purification for PM2.5 speeds up. Furthermore, the efficiency of purification for PM2.5 improves also. The initial filter and the activated carbon filter pretreat the air through turbine fan; they also reduce the damage for the subsequent HEPA filter caused by bacteria and reduce the unnecessary loss. At the same time, we sealed gap between the filter and the device box to ensure the accuracy of the collected data after purification. That makes sure that unpurified air cannot penetrate the filter to disturb PM2.5 numerical monitoring. This kind of design/set-up keeps the reliability of monitoring data for the subsequent analysis and calculation with great convenience.

According to the dynamic experimental results shown in Table 2, the device can achieve the air purification efficiently. To avoid damage to the purification device, the device should be kept far away from smoke environment. The timely replacement of the early filter and activated carbon filter are necessary to maintain the efficiency the indoor air purification.

Table 2. The dynamic testing results of air purification for indoor PM2.5

Experimental Results* Concentration Time	1st	2nd	3rd
Before Purification	289	276	293
30s	246	226	249
50s	237	209	227
100s	192	183	170
200s	96	92	89
300s	45	43	39
Efficiency (%)	84.4	84.4	86.7

*Note: The simulated testing environment is 500x500 mm^2

5. Bluetooth data transformation between mobile phone and data transfer

HC-05 Bluetooth serial module is used to connect the Arduino single chip computer [5, 7]. Thus, communication with Android system, real-time monitoring and the data of long-distance transportation can be realized. Because Arduino has only a pair of clear serial port for voice module communication, we access the information through the Arduino with Software Serial Library function and set the 4,5 port as a soft serial port to achieve real-time communication. Through the mobile app, the real-time PM2.5 value has been consistently displayed. According to the program, the voice module can broadcast the corresponding real-time air quality level simultaneously as well.

6. Convection fan design and intelligent fan speed control

For further better indoor air purification results, with two small fans placed on the purifier and in the opposite direction, we set-up convection fan system to enhance air circulation. When the indoor PM2.5 value is high, the convection fans are turned on and air convection increase. Thus, the efficiency and scope of purification for indoor PM2.5 can be greatly enhanced, and the surrounding air quality is improved also.

HC-05 Bluetooth module equipped with fan is still used for state transmission and semi-automatic control. Exhaust fan is added for intelligent speed control to coordinate the efficiency and balance the noise. When the air quality is good, the purifier will automatically set the speed to 0 for energy saving. The PWM frequency for the coming Arduino is only 256, and this does not meet the fan speed at 20KHZ. We modified the timer pre-bit and PWM output mode, so that the frequency of 3IO just meets the requirements.

7. Conclusions

We have developed the intelligent monitoring purifier with high removal capacity and efficiency over 84% for indoor PM2.5. Integrated with the removal of PM2.5 and even smaller particles with the aid of HEPA filter and the advanced multi-functions achieved by electrical devices, including the intelligent monitoring, voice broadcast for the PM2.5 concentration, and Bluetooth data transportation.

It is believed that indoor PM2.5 air purifier with intelligent monitoring system can be used as a stand-alone device to achieve a healthier indoor living environment.

8. Acknowledgement

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9. References

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