Portable air purifier based on negative ions

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Abstract

In recent years, negative ion generators have been widely used to solve increasingly serious air pollution problems. In order to alleviate the harmful effects of smog, a portable negative ion purifier is proposed. It can keep about 3 cubic meters of fresh air around the human body while helping children, women and the elderly, who are most vulnerable to respiratory diseases, avoid inhaling second-hand smoke. The purifier can make people breathe healthily and relieve fatigue. It can also greatly improve the quality of life and maintain the health of its users. This paper mainly describes the theoretical and practical research of this negative ion air purifier. Theoretical research includes the basic principles of negative ions and the rationality of design. Practical research includes a functional introduction of the various parts of the air purifier.

Key words: *air purifier, negative ion, product design*

Introduction

With the advancement of industry, industrial dust and motor vehicle exhaust are becoming the biggest culprit of air pollution which has been one of the most serious issues worldwide. When people work in indoor facilities full of fine particles, they are susceptible to various respiratory diseases. What's more, the World Health Organization had declared that every year more than 100,000 people die of asthma all over the world, 35% of whom are children, due to air pollution. According to statistics, most of recent Chinese leukemia cases are also induced by air pollution. Therefore, the air purifier has become a necessary electrical appliance for any family that wants to improve the air quality indoors. But the traditional air purifiers are so big that most of them seem to be too clumsy to be moved. To address this issue, a portable air purifier has been designed.

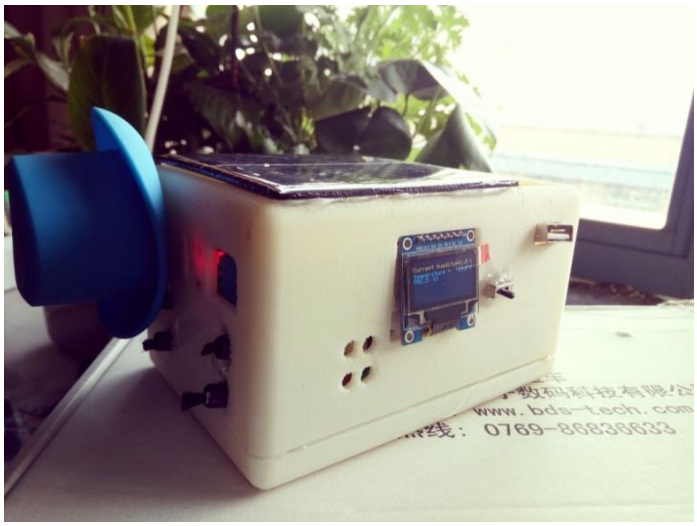


Figure1 air purifier (at work)

Recently, the negative ions generator has been widely used to purify air. As an important eco-tourism resource, aero-anion has multiple air purification functions, such as sterilization and dust reduction, hailing itself as "air vitamin and auxin". [1] Particulates with positive ions, for instance, soot and dust, can adsorb negative ions so easily that these particulates can be coagulated and become large particles. Particles and dust with the diameter of less than 0.01 microns are very difficult to remove, for example cigarette smoke and sensitized particles. However, they can be more effectively coagulated through aero-anion, which explains how negative ions can decrease the dust in the air and improve the air quality consequently.

The traditional air purifiers use a fan to pump air. The filter screens are used to adsorb the dust so that it can purify the air. Unfortunately, the filter screens need to be replaced regularly, while the air purifiers with negative ion generators do not need any extra consumables. Under the same circumstance, the negative ion air purifiers can be much smaller than the traditional ones. This means that people can always breathe clean air when they travel with a negative ion air purifier.

Description of the air purifier

A. Structure of the air purifier

The working process of the air purifier is described with Fig. 2. The Fig.2 shows the various components of the air purifier.

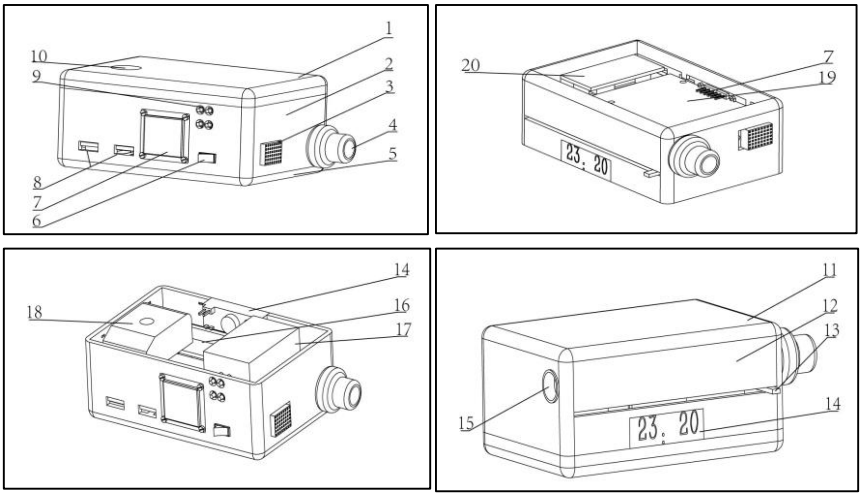


Figure2 air purifier

1: case, 2: cover, 3: temperature sensor, 4: humidifier, 5: top panel, 6: switch, 7: liquid crystal display, 8: charge port & USB port, 9: window for the negative ion generator, 10: window for the dust sensor, 11: solar panel, 12: rear panel, 13: slider, 14: 4-digit digital tube, 15: pipe for the humidifier, 16: isolation panel, 17: negative ion generator, 18: dust sensor, 19: Arduino development board, 20: boost chip

The process is as follows: turn on the switch (6 in Fig. 2) on the front side of the air purifier so that the entire device can work by battery power. The control system is powered up and the Arduino development board (19 in Fig. 2) starts working.

The dust sensor (18 in Fig. 2) and the temperature and humidity sensor (3 in Fig. 2) of the detection system are working. The dust sensor and the temperature and humidity sensor can transmit the received signals to the development board. Then the value of PM2.5, temperature and humidity can be displayed on the liquid crystal display (7 in Fig. 2).

The value of PM2.5 in the air detected by the dust sensor is compared to the threshold value. The threshold value is in compliance with the Chinese air quality standard. If the detected value of PM2.5 exceeds the threshold value, the Microcontroller Unit will activate the negative ion generator. When the negative ion generator (17 in Fig. 2) has worked for more than 30 minutes, the generator will be automatically turned off, because generating negative ions for a long time not only wastes power but also causes harm to health. A 4-digit digital tube with a DS3231 clock chip (14 in Fig. 2), in which a button battery is installed, is embedded in the rear front of the case so that the time can be displayed in real time. And the clock chip can always work, whether the air purifier is turned on or turned off. Theoretically, a button battery can be used for two to three years. The time, which is displayed on the liquid crystal display, can be modified by two buttons mounted on the back of the digital tube.

A humidifier (4 in Fig. 2) is inserted in the case that can be directly used when the air purifier works. By moving the slider (13 in Fig. 2), the pipe (15 in Fig. 2) of the humidifier can outstretch. When the pipe is inserted into the water, the humidifier can humidify the air in

the room. What's more, the humidifier can also work when it is pulled out and put in a cup, which is filled with water. The humidifier can be operated by comparing the detected temperature and humidity value with a threshold value or can be manually switched on.

The air purifier also reserves two ports (8 in Fig. 2) on the case. There are two solar panels (11 in Fig. 2) on the cover. The solar panels are used to charge the battery in the air purifier. If it is cloudy and the solar panels cannot work well, one of the charging ports can be used to charge the device, and the other, a USB port, can be used to charge other digital products such as smartphones.

B. Electrical Design of the air purifier

(1) Detection of sensor signals: two sensors are used, which are dust sensor and temperature and humidity sensor. Both sensors are connected to the Arduino development board and the detected signals are returned to the main control board. The dust sensor is used to detect the value of PM2.5. It consists of an infrared light-emitting diode and a phototransistor, which are installed diagonally. The optical characteristic is used to detect the reflected light of the dust in the air. The output is an analog voltage, which is proportional to the dust concentration. Its sensitivity is 0.5V/0.1mg/m^3. There is a hole in the center of the sensor to let the air flow freely and the LED emits directionally light and the dust concentration is determined by detecting the light refracted by the dust in the air. Temperature and humidity detection sensor using DHT11 sensor can measure the humidity in the range of 20%-95% and the temperature in the range of 0-50 degrees.

(2) Function of the liquid crystal display: it is a 0.96-inch liquid crystal display. It can display 128 * 64 dot matrix monochrome images or other monochrome images, which are smaller than 128 * 64. It can also display Chinese characters. It can display 8 words * 4 lines, when the Chinese character is in a 16*16 dot matrix. It can display 10 words * 4 lines, when the Chinese character is in a 12*12 dot matrix. It can display 16 words * 4 lines, when the Chinese character is in an 8*16 dot matrix. It can display 21 words * 8 lines, when the Chinese character is in a 5*8 dot matrix.

(3) Solar energy: 5 volt, 1 watt miniature solar panels are used to collect solar energy for storage. The Arduino development board uses 5V power supply and can be directly powered. At the same time, the 5V power supply is also used to charge digital products such as mobile phones. The negative ion generator uses 12V power supply, so the voltage of the solar panels needs to be raised to 12V with the boost chip. Considering the low efficiency of the solar panel, the air purifier is designed so that it can be charged by another power supply.

(4) Programming: the Arduino R3 development board is used as the main control board to program. The program syntax is simple. And the development board is safe and reliable. The value detected by the sensor can be returned to a pin. The value of the pin can be read by the development board. After the calculation the operating state of the negative ion generator and LCD display can be changed.

C. Calculation for the design

(1) Negative ion generator

The core part of this design is the negative ion generator, which connects the DC negative high voltage to the release tip made of metal or carbon. It uses the high voltage corona of the tip DC to generate a high corona, and emits a large amount of electrons (e-) at high speed. However, the electrons cannot exist in the air even for a while (only nS-level electrons can exist in the air), it will be immediately captured by oxygen molecules (O_2) in the air, resulting in air negative ions. The size of the ion is expressed by the ion mobility. The definition of the ion mobility is: the moving speed of one ion in the unit intensity electric field (1V/cm). The mobility higher than 1.5 square centimeters / (v/s) is a small particle size negative ion; mobility lower than 0.001 square centimeters / (v/s) is a large ion; between the two is a medium ion. Medical research shows that only small particles of negative ions can pass through the blood-brain barrier and enter the human body for health care or treatment. The amount of ions generated is related to the wind speed. The wind speed is usually less than 10 m/s, the pulse voltage is generally 50 kV, and the pulse frequency is 50 Hz. When the input power is 50W, the number of ions generated is about $5x10^{10}$~$5x10^{11}$ per second.

(2) Solar energy efficiency calculation

In the upper boundary of the Earth's atmosphere, at an astronomical unit from the Sun, the solar radiation energy in each time unit in unit area, which is perpendicular to the Sun, is called a solar constant S0. At this time, the sun is regarded as a point source, and the absorption of the atmosphere is not considered. However, the intensity of solar radiation near the actual surface of the Earth is affected by atmospheric absorption. Atmospheric absorption also affects the solar spectral distribution. At the same time, the radiation intensity is also affected by the height of the sun. To describe this relationship, air mass (AM) is introduced. The height of the sunlight passing through the atmosphere perpendicularly into the sea level is taken as an atmospheric mass AM1 with an irradiance of about 1000 W/M^2. The distance that the sun passes through the atmosphere at any other position is Proportional to AM1 and the scale factor is sin a. ‘a’ is the elevation angle of the sun. The air quality in outer space is AM0. As the sun's height decreases, the distance through the atmosphere increases. The air quality is higher than 1. The air quality closest to the real life situation is AM1.5. At this time, the solar elevation angle is 41.8 degrees, and the irradiance is 963 W/M^2. Therefore, the International Standards Organization defines AM1.5 as the standard condition for terrestrial photovoltaic modules, and the irradiance is set at $1000W/M^2$.

$$\text{Solar panel efficiency} = \frac{\text{Open circuit voltage} \times \text{Short circuit current} \times \text{Fill factor}}{\text{area of the solar panel} \times \text{Light amplitude}} \times 100\%$$

$$\text{Maximum power} = \text{area of solar panel} \times 1000 \times \text{Solar panel efficiency}$$

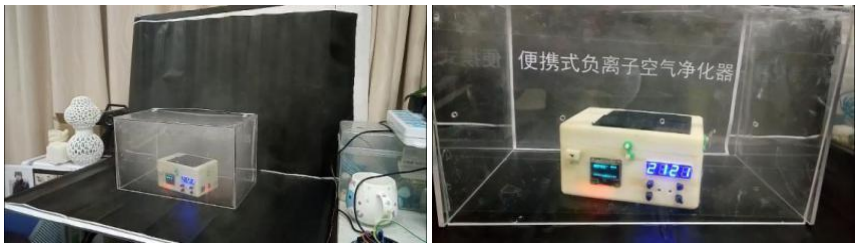
(3) PM2.5 concentration measurement calculation

The PM2.5 dust sensor is developed according to the principle of light scattering. Particles and molecules will scatter light under the illumination of light and absorb a part of energy of the light. When a beam of parallel monochromatic light is incident on the particle field, which should be measured, it is affected by scattering and absorption around the particles, and the light intensity is attenuated. In this way, the relative attenuation rate of the incident light passing through the concentration field to be measured can be obtained. The relative attenuation rate basically linearly reflects the relative concentration of the dust to be measured. The intensity of the light is proportional to the strength of the photoelectrical converted electrical signal. By measuring the electrical signal, the relative attenuation rate can be obtained, and then the concentration of dust in the field to be measured can be determined.

The PM2.5 sensor is designed to sense dust particles in the air. It consists of an infrared light-emitting diode and a phototransistor, which are installed diagonally. Their optical axes intersect. When dusty air flows through the intersection of the optical axes, the infrared light will be reflected, the intensity of the reflected light is proportional to the concentration of dust. The phototransistor enables the sensor to detect the reflected light in the air, even if very small particles such as tobacco smoke can be detected. The infrared light emitting diode emits light and the reflected light is generated by the dust. At the same time, the receiving sensor detects the light intensity of the reflected light. The output signal determines the concentration of the dust according to the intensity of the output signal and distinguishes the concentration of different dust particles by outputting two different pulse width modulation signals (PWM).

(4) Air purifier efficiency experiment and calculation

The Experimental steps: At first, put a burning mosquito coil and the air purifier in a sealed transparent box. The volume of the box is 0.01 cubic meters. Then, the mosquito coil would burn out in 90 seconds. At the same time, the air purifier would automatically work in 2 minutes. (In Fig.3) Start timing as soon as the air purifier starts working. Next, observe the values on the display. At last, record the value on the display and the time it takes.



(A) (B)

Figure3 A: the air purifier in the smoking condition

B: the effect of the purification

According to the instruction of the mosquito coil, the mosquito coil can generate 106mg

smoke per minute. When the mosquito coil burns out, the concentration of smoke in the box is 15.9mg/m^3. After 54 seconds, the value detected by the air purifier is 3.2 mg/m^3. As a result, the efficiency of the air purifier is about 235.2mg/(m3 • s).

(5) Air purifier parameters

Items	Unit	Value
Input voltage	V	12
Output voltage	KV	-3.8±1
Negative ion concentration	PCS/cm^2	>3x106
Ozone concentration	PPM	<0.05
Rated power	W	<1
Input Current	mA	<25
Operating temperature	℃	-10～+60
Operating humidity	%	<95%
Electromagnetic Compatibility	db	3~5
Weight	g	688
Dimensions	mm	120*80*53

Conclusion

The main idea of the design is to make the air purifier portable. It can keep about 3 cubic meters of fresh air around the human body. This product combines the sensor and the control module to display the analog value detected by the dust sensor and the temperature and humidity sensor on the LCD and can also displays the time. Solar panels are used to power all components. The excess electrical energy is stored for charging the phones.

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